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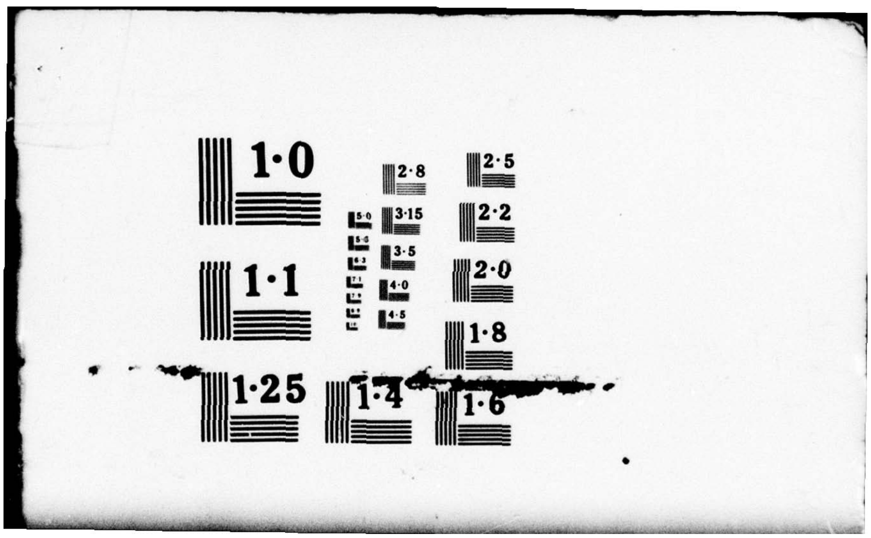

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MAINTENANCE TRAINING SIMULATORS AT AIR FORCE TECHNICAL TRAINING CENTERS: PRESENT AND POTENTIAL USE

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December 1978
Final Report for Period June 1977 – August 1978

Approved for public release; distribution unlimited.

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19 REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER 18 AFHRL-TR-78-77	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) 6 MAINTENANCE TRAINING SIMULATORS AT AIR FORCE TECHNICAL TRAINING CENTERS: PRESENT AND POTENTIAL USE.	5. TYPE OF REPORT & PERIOD COVERED 9 Final rept. June 1977 – Aug[redacted]78,
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 C. Dennis Fink, Edgar L. Shriver	8. CONTRACT OR GRANT NUMBER(s) 15 F33615-77-C-0051
9. PERFORMING ORGANIZATION NAME AND ADDRESS Kinton, Incorporated, 1500 N. Beauregard Street, Suite 205, Alexandria, Virginia 22311	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 63751F 23610101 16 2361 17 01
11. CONTROLLING OFFICE NAME AND ADDRESS HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235	12. REPORT DATE 11 Dece[redacted]78
	13. NUMBER OF PAGES 134 12 142p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Technical Training Division, Air Force Human Resources Laboratory, Lowry Air Force Base, Colorado 80230	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

maintenance training simulators
questionnaires
simulation
technical training
use of instructor surveys

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this study was to identify the present and potential need for maintenance training simulators in support of Air Force technical training and to assess the usefulness of instructor surveys in identifying the need for simulation. Data were collected through the use of survey questionnaires and instructor interviews. Results indicated a willingness on the part of most instructors to use low cost/fidelity simulators as supplementary training devices but not as replacements for actual equipment trainers. In addition, a simulative potential ranking formula was employed which resulted in the identification of 36 high priority candidates for simulation. Thirty-two of the 36 candidates represented electronic equipment, particularly test benches. The validity of the data collected using the questionnaire methodology is discussed along with the problems inherent in using instructors to identify

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solutions for training problems. It was concluded that the survey procedure was useful for identifying simulation candidates but that final decisions on simulator usage should be left to simulation experts. Recommendations are provided for modifying the questionnaire formats and further study of the simulation candidates identified in this study.

SUMMARY

Objective

This study was conducted as part of an overall Air Force effort to reduce the cost of training maintenance personnel. The study's primary objectives were: (1) to identify the present and potential need for maintenance training simulators in support of training conducted at Air Force Technical Training Centers; and (2) to assess the usefulness of instructor surveys as a means for identifying the need for simulation.

Methodology

Data for the study was obtained through the use of two survey questionnaires, supplemented by discussions with instructor personnel and observation of training equipment. The questionnaires were administered to small groups of instructors and were preceded by a briefing on the purpose of the project and on how various types of training devices can be employed to support various stages of learning. The respondents were 98 Air Force senior instructors representing 100 maintenance courses conducted at Technical Training Centers located at Chanute, Keesler, Lowry and Sheppard AFBs.[1] These courses were selected to cover a wide variety of equipment.

Questionnaire A, "Survey of Instructor/Training Personnel Opinions Regarding the Use of Low and Medium Cost/Fidelity Training Devices and Simulators", was designed to collect information about instructor acceptance of the potential use of various training devices and media for maintenance training. Questionnaire B, "Survey of Training Equipment Problem Areas and New Simulator Requirements for Maintenance Courses", was designed to: (a) Part I--identify problems with existing maintenance trainers; and (b) Part II--identify actual equipment trainers (AET) which might be replaced or supplemented by maintenance simulators. For each trainer identified on Part II of Questionnaire B, data were obtained regarding the unit cost of the trainer and the number of hours it was non-available for training due to unscheduled maintenance during a recent 12-month period.

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[1] Two of the instructors represented two courses each.

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Findings

Responses to Questionnaire A indicated that most instructors would be willing to use lower cost/fidelity training devices and media as supplements to the use of AETs but not as replacements for AETs. Most instructors reported that they relied heavily on actual equipment trainers and wished to continue doing so. Most instructors, regardless of the type of equipment covered in their course or the level of the course, provided similar answers to most questions contained in Questionnaire A. However, instructors of 5- and 7-level courses were less inclined to favor the use of simulators. Also, instructors of electronic courses were more apt to respond favorably to questions about the effectiveness of simulators.

Responses to Questionnaire B, Part I indicated that most instructors were satisfied with their training equipment although only 43 percent judged their equipment to be reliable.

In response to Questionnaire B, Part II the instructors identified 80 expensive AETs and provided a variety of information about each. Those trainers were rank-ordered by the investigator in terms of their "simulation potential". This "potential" was calculated by devising a ranking formula which included a variety of factors which affect either the acquisition or life-cycle trainer costs, availability of trainer for training, or trainer effectiveness. Using this formula the authors identified 36 actual equipment trainers which appeared to be high priority candidates for simulation. Thirty-two of these represented electronic equipment, test benches in particular. Further analysis of the 36 high priority simulation candidates revealed that 31 of them had been listed by instructors known to be involved or at least quite familiar with ongoing simulation projects at Lowry, Kessler or Chanute AFBs.

Discussion

The usefulness of Questionnaires A and B for identifying simulation candidates is discussed. Questionnaire A and Part I of Questionnaire B are not found to be useful. On the other hand, the data provided by Part II of Questionnaire B is judged to serve as a useful way of rapidly identifying equipment which might be simulated. It is pointed out that simulation experts then should make the final determination as to what equipments to simulate based on a detailed examination of specific courses and training equipments.

The validity of the data obtained through the use of Questionnaire B, Part II is examined and it is suggested that the data can be used to determine the relative cost, reliability, effectiveness, etc. of trainers but not their absolute cost-effectiveness.

Reservations are expressed about the use of instructors for proposing solutions to training problems. It is suggested that instructors be used to identify training problems, especially areas where more effective trainers are needed; solutions to such problems are more apt to come from training experts who are more familiar with the latest instructional techniques and options.

One section of the report is devoted to a discussion of the factors suggested for consideration when making decisions about whether or not to employ maintenance simulators or AETs. Twenty-three factors are discussed under five categories--acquisition costs, life-cycle costs, trainer availability, trainer effectiveness and training environment.

The impact of Task Oriented Training (TOT) programs on maintenance training is discussed. Under these programs the locus of training is shifted from an institutional to a field setting. It is suggested that the implementation of TOT programs will considerably reduce the need for maintenance trainers at Technical Training Centers but may greatly increase requirements for and change the nature of such trainers at field training sites.

Conclusions and Recommendations

It is concluded that instructor survey procedures and instruments of the kind represented by Questionnaire B, Part II can effectively identify courses which have expensive, problem-ridden training equipment which may be candidates for simulation. The authors caution that the final decision to substitute simulators for AETs should be based on an in-depth analysis of course training requirements by experts in simulation technology. It is concluded also that the 36 high priority candidates for simulation identified during this study should be analyzed in further detail to determine which ones should be considered for simulation in the near term. Study recommendations are: (1) to merge Parts I and II of Questionnaire B and administer the revised questionnaire to selected instructors of all TTC maintenance courses on a bi-yearly basis; and (b) to develop procedures for conducting an in-depth study of those equipments which, according to survey data, are candidates for simulation.

PREFACE

This document represents a portion of the work performed under Air Force Contract F33615-77-C-0051. The contractor was Kinton, Incorporated, Alexandria, Virginia 22304. Dr. Edgar L. Shriver was the principal investigator; the project manager was Dr. C. Dennis Fink. Sponsor for the project was the Air Force Human Resources Laboratory, Lowry AFB, Colorado. Major Dennis Downing was AFTM.

As part of this project a literature review was prepared. The title of that document was "Simulators for Maintenance Training: Some Issues, Problems and Areas for Future Research" (AFHRL-TR-78-27).

The authors wish to acknowledge the cooperation and assistance of the many persons who contributed to this effort. In addition to the 98 instructors who completed questionnaires for the study, local contacts at Air Force Technical Training Centers played an invaluable role in arranging for and executing the details of the survey. These persons were Mr. Joe Jones and CMSGT R. L. Spreitzer, 3700 TCHTW/TTGOR, Sheppard AFB; Dr. Nathan Walker and Mr. Leighton Bond, 3300 TCHTW/TTGOR, Keesler AFB; Mr. B. Robertson and Mr. W. J. Richardson, 3350 TCHTW/TTGOR, Chanute AFB; and M/SGT Lester Kilpatrick, 3400 TCHTW/TTGOR Lowry AFB.

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MAINTENANCE TRAINING SIMULATORS AT AIR FORCE TECHNICAL TRAINING CENTERS: PRESENT AND POTENTIAL USE

OBJECTIVES

This study investigated the use of various types of training devices in equipment maintenance courses conducted by the U. S. Air Force. The primary study objective was to identify the present and potential need for maintenance simulators[1] in support of resident training conducted at Air Force Technical Training Centers. A second major objective was to investigate the usefulness of survey procedures for identifying resident training equipment (RTE) simulation candidates. A third and lesser objective was to obtain opinions about the use of low to medium cost/fidelity training devices in place of or in addition to actual equipment trainers (AET).

BACKGROUND

The Air Force and the other services make extensive use of simulators. They are used to train individuals to perform operating procedures; to train crews to operate aircraft and ships; and they are extensively used for pilot training.

During the past 30 years a number of research projects, many of which were supported by the Air Force, have demonstrated that simulators can be used to teach certain maintenance skills. In particular it has been shown conclusively that the controls and external indicators, and the signal flow characteristics of electronic equipment can be simulated accurately enough so that the resulting simulators can be used to teach operator skills and the conceptual aspects of troubleshooting.

During the past decade, in part due to the requirements of the space program, the capability for modularizing and miniaturizing equipment so that it can be more easily maintained has become highly developed. Recently designed equipment, especially electronic equipment, is interlaced with sensors which monitor the functioning of

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[1]For this study a definition of "simulator" developed by Gagne (6) was adopted. He states that "a simulator is generally understood to be a kind of training device which has a high degree of resemblance to operational equipment, particularly with respect to the display, the controls, and the way one affects the other when in operation."

equipment subsections and components. These sensors are connected to front-panel displays; through the manipulation of front panel controls and the interpretation of front panel displays and indicators, it is possible to isolate malfunctions to a fairly small portion of the equipment without making internal checks on the equipment. Even more recently, with the advent of built-in test equipment (BITE), it has become possible to use mini-computers to both check out and to troubleshoot the BITE equipment itself, and then to test and troubleshoot the equipment into which the BITE has been incorporated.

Because of the foregoing and other developments the job of a maintenance technician has become more like that of an equipment operator. The maintenance man, at least at the organizational level of maintenance, now can troubleshoot many electronic equipments through the use of built-in test equipment and front panel controls. By this means, sometimes aided by built-in computers, the technician can isolate a fault to a particular "line replaceable unit" (LRU). Going one step further, this replaceable unit often can be mated to a computer-driven test set and a computer program employed to check out and to locate faults within the LRU. The maintenance tasks involved in this later activity are operator-like tasks yet they are considered to be part of the group of tasks which comprise maintenance at the intermediate level.

Because of advances in miniaturization and the development of mini-computers it is now possible to simulate the operational and signal characteristics of electronic equipment. Furthermore, because the job of the maintenance technician has become more like that of an equipment operator, it is now reasonable to consider the use of simulators for training maintenance personnel. Advocates of the use of simulators for maintenance training always have felt that simulators were at least as effective as actual equipment trainers (AET), and numerous studies have demonstrated that troubleshooting skills can be taught more effectively by the use of simulators. (5)

There is, however, another feature of simulators which currently has caught the attention of training personnel. With some exceptions, simulators are less costly to design, develop and maintain than is the equipment they represent. For example, the life cycle cost of a simulator may be only 10-20 percent of that for its equipment counterpart (3, 12, 13). Because of this possibility, and because of the current emphasis on reducing the cost of training, the potential of simulators is being widely explored.

The present study is only one of a number of recent studies supported or conducted by the Air Force which deal with the potential use of simulators. The Technical Training Division of the Air Force Human Resources Laboratory has purchased a simulator for the 12A6883 Converter/Flight Control Test Station for the F-111D Aircraft, and during CY 1978 will investigate the effectiveness of and the cost benefits associated with that trainer. The 6883 test set is a test bench used to maintain certain F-111D avionics components. During the early months of CY 1977 the Air Training Command (ATC) asked the Technical Training Centers to identify those actual equipment trainers (AET) which in their judgment might be replaced by simulators. As part of the present project, a literature review (5) was prepared which described the state of the art with respect to the use of simulators for maintenance training. Currently some of the Air Force's Technical Training Centers are actively exploring the possibility of developing in-house one or more maintenance training simulators. And, of course, because of the current interest expressed by all military services, industry is actively expanding and improving its simulation capabilities.

METHODOLOGY

Survey Questionnaires

The data for this study was collected through the use of questionnaires, discussions with instructor personnel and observation of training equipment. Information about field training detachments and unit training was obtained from various persons familiar with that type of training, and from another study conducted by the Contractor. That study (7) was concerned with documenting Air Force procedures for identifying the requirements for and for procuring training equipment. Information about the use and potential use of various types of training devices at Technical Training Centers was obtained primarily through the use of two questionnaires.

Questionnaire A: Survey of instructor/training personnel opinions regarding use of low and medium cost/fidelity training devices and simulators. This questionnaire was designed to identify present and potential uses of various kinds of training devices and media. A copy of the questionnaire is contained in Appendix A. The questionnaire covered seven categories of training devices which collectively

encompassed all of the various types of training devices used throughout the Air Force. The categories of trainers covered were as follows: Classroom Demonstrators; Nomenclature and Parts-Location Trainers; Cue Discrimination Trainers; Part-Task Trainers; Troubleshooting Logic Trainers; Job Segment Trainers and Simulators; and Actual Equipment Trainers (AET) and Operational Equipment.

Questionnaire A was subdivided into seven sections, each section covering a particular category of training equipment. A questionnaire section began with a short review of the type of trainer covered in that section. In some cases this review contained a brief description of research findings with respect to the use of the class of trainers covered in that section.

Each section of the questionnaire contained from three to nine questions. Most questions were multiple response questions. However, about 25% of the questions required an open-ended response.

Because of the length of the entire questionnaire, it was divided into two parts, Part I and Part II. Any particular respondent answered only the questions contained in either Part I or Part II.

Questionnaire B: Survey of Training Equipment Problem Areas and New Simulator Requirements for Maintenance Courses. The purpose of this questionnaire was twofold--to identify major problem areas associated with current training equipment, and, to identify actual equipment trainers which might be replaced by simulators.

Part I of Questionnaire B contained seven multiple option response questions each dealing with a problem area relating to the use of training equipment. The problem areas related to: sufficient numbers of training equipment; adequacy of training equipment; non-availability of training equipment; cost restraints on the use of training equipment; constraints regarding the modification of training equipment; training equipment reliability; and the extent to which critical training areas were supported adequately by training equipment.

Part II of Questionnaire B asked the respondents to list expensive actual equipment trainers employed in specific maintenance courses. They then answered a number of questions about each listed AET. The instructions were to list AETs which had an estimated current unit cost value of around $100,000.00 or more. For each trainer listed, the respondent indicated whether or not the AET was: effective,

reliable, easy to maintain, easy for students to use, easy for instructors to use, and whether or not the trainer was used to teach troubleshooting. In addition, for each listed AET the instructors reported on how many AETs they currently had; whether or not they needed more AETs; and whether or not they would be willing to use simulators in addition to AETs, to replace some AETs, or to replace all AETs.

Appendix B contains a copy of Questionnaire B. Question 1, Part II of the questionnaire was used to judge the effectiveness of the listed AET. Question 4 of Part II was used to judge the potential for using simulators along with or in place of actual equipment trainers.

Respondents

The intent of the survey was to collect information about the use of training devices employed to support 30 equipment maintenance courses conducted at each of four Technical Training Centers located respectively at Chanute, Keesler, Lowry, and Sheppard AFBs. For a variety of reasons, to include the termination of a number of courses, data were obtained for only 100 instead of 120 courses. This information was supplied by 98 different instructors. Each instructor represented a maintenance course which made fairly extensive use of equipment. With rare exceptions, the survey respondents were very senior military or civilian instructors.

The courses covered during this survey were selected as follows: contractor personnel went through the AF school catalog (AFM 50-5) and on the basis of reading course titles and abstracts selected 30 courses conducted at each of the four Technical Training Centers. The courses selected were those which appeared to make heavy use of fairly expensive training equipment. Local contacts at each of the four Technical Training Centers were asked to identify a senior instructor for each course who would complete the questionnaires. In some instances, the local contacts substituted other courses because: the courses selected by the contractor had been dropped, did not make extensive use of training equipment, or other courses which did make extensive use of expensive training equipment had been omitted from the survey list. A list of the courses surveyed is contained in Appendix I.

Table I shows the types of equipment or weapon systems represented by the 100 surveyed courses. Most courses covered the maintenance of electronic or electro-mechanical equipments.

Table I. Classification of Courses Surveyed in Terms of Types of Equipment Covered by Course

Type of Equipment	Number of Courses Covered by Survey
Electronic	49
Electro-Mechanical	24
Precision/Measuring	7
Electrical/Telecommunications	8
Engines (Aircraft)	4
Hydraulic	3
Miscellaneous	5

Administrative Procedures

Prior to visiting each Technical Training Center (TTC), the local project contact was sent a detailed set of instructions regarding how to support the survey effort. The instructions included: a suggested schedule of events, a list of the courses to be covered during the survey, a description of the type of instructor who should participate in the survey, and a list of other organizations which would be contacted during the visit and the reasons for these contacts. These other organizations included the Consolidated Maintenance Squadron, the Training Services Branch, and the various Technical Training Groups.

Prior to the survey the survey procedures and the survey questionnaires underwent a field test at Lowry AFB, Colorado and appropriate revisions were made to the questionnaires and to the survey methodology.

At each Technical Training Center, the questionnaires were administered during three different sessions. The number of respondents at each session varied from 4 to 13. It took most respondents about 1½ hours to answer the two questionnaires. Each respondent first answered either Part I or Part II of Questionnaire A. They then answered the questions contained in Questionnaire B. The numbers of instructors answering Part I and Part II of Questionnaire A were 59 and 41, respectively. All respondents answered Questionnaire B.

At the beginning of each survey session the respondents received a short briefing on the overall objectives of the project. That briefing material is contained in Appendix C. Following that the respondents received a rather extensive briefing on the relationship between stages of learning and types of training equipment. The purpose of that briefing was to present a particular point of view. Namely, that for any complete maintenance training program a mix of training devices and media should be employed. The briefing promoted the notion that one should attempt to fully utilize low cost and low fidelity trainers before moving on to more expensive and/or higher fidelity training devices. The briefing also was used to dispel the notion that maintenance simulators could be employed to completely replace actual equipment trainers. It was noted that whereas some prior efforts to promote the use of simulators had suggested that simulators could become complete replacements for

actual equipment trainers, the current study took a somewhat different position, namely, that both simulators and actual equipment trainers have an important role to play in maintenance training and in order to decide what that role should be one has to look at the total training program, both resident and non-resident, for a maintenance specialty. Because of the importance of this briefing as a stage-setter for completing the questionnaire, it is reproduced in its entirety at the end of this section along with the two viewgraphs (Tables II and III) used with the briefing.

The two briefings, the overall project briefing and the stages of learning briefing, and the question and answer session which followed the second briefing, collectively took about 30 minutes to accomplish.

Other Data Collecting Activities

At the end of each questionnaire session, the contractor compiled a list of actual equipment trainers which had been reported on Part II of Questionnaire B. These were considered to be training equipments which might be candidates for simulation. This list was given to the TTC's Resources Management Branch who obtained, for each listed AET, the identification number, the unit cost, and the approximate year of acquisition by the TTC. In most instances, this information was obtained from the equipment custodian for the Technical Training Group.

Once the ID number for each listed AET had been determined, the list of ID numbers was forwarded to the Consolidated Maintenance Squadron with a request to prepare a printout of unscheduled maintenance actions for each listed trainer for the period between 1 July 1976 and 30 June 1977. In most instances, it took two or three days to obtain the requested printouts. Once they had been prepared they were mailed to contractor facilities.

Contractor personnel spent about four days at each Technical Training Center. The last two days of each visit were spent primarily on visiting various Technical Training Groups and receiving a short briefing on the nature of and use of major types of training equipment. For the most part, this was equipment that had been listed on Part II of Questionnaire B.

Data from Concurrent Projects

During the conduct of this study, other Contractor personnel were involved in two other maintenance studies for the Air Force. One of these studies entailed extensive travel and interviewing at a variety of AF bases within CONUS. During these visits, information was obtained about the activities of field training detachments, and unit training activities at both TAC and SAC installations. In addition, a variety of information was collected about AF ISD (Instructional System Development) activities, the procedures for identifying training requirements, the various types of training equipment and simulators used for unit training, and information about the simulators which will be used for maintenance training on the F-16.

* * *

Stages of Learning Briefing

For the next few minutes I would like to talk to you about the relationship between training devices and stages of learning. The reason for discussing this material at this time is to review for you a particular point of view, namely, that training devices should be designed to support a particular stage of learning.

We all are aware that students progress through various stages of learning. During the first stage of learning progress may be very slow and students may easily be overwhelmed by too much information. As learning progresses they become able to take on more difficult learning tasks.

As students progress through a course they learn new tasks one by one. For each new task they go through all stages of learning, from a novice stage, through an uncoordinated skill stage, through a coordinated skill stage in a training setting, and finally through a stage where they acquire full job proficiency on operational equipment. Often it is difficult to tell when a person has entered a new stage of learning, and it is not essentially important to break up the learning process into four stages; three or five stages might describe the process equally well. What is important to remember is that the research evidence strongly suggests that the effectiveness of various training methods and devices depends on using them to support a particular stage of learning.

On the first slide here you see that four stages of learning have been listed on the left. The novice student enters a maintenance course and progresses through three stages of learning. Usually this completes his formal training. He then is assigned to the field where, through on-the-job training and practice, he becomes proficient at maintaining equipment. At this point his supervisor is willing to certify him as a journeyman mechanic.

On the right-hand side of the slide are listed the general training objectives usually associated with each stage of learning. During the first stage the training goal is to teach a variety of enabling objectives. The student learns about his job, equipment names, parts locations, and so on. Also, during this stage he may be given his first exposure to theory.

During the second stage of learning the student concentrates on learning procedures, how to perform part-tasks, and how to use various tools and simple test equipment. The general training objective is to get the student to a point where he can perform without error, "but these responses do not have to be quick, smooth, or coordinated." During this stage the student may acquire an understanding of theory but he will not know how to apply it to practical problems.

During the third learning stage the student practices until he can skillfully perform in the training environment. He learns to use theory to solve certain problems which he may encounter on the job; he learns to perform operational checks, to remove and replace components, to locate malfunctions, and so on. The student may even have an opportunity to practice some of these tasks on real equipment, but the amount of this practice often is quite limited. Thus, at the end of the third stage of learning the student has met course standards but still needs on-the-job training and practice before he can perform in accordance with job requirements. This training and practice occurs during the fourth stage of learning.

Now let's look at the next slide. On this slide we have related stages of learning to the general types of training devices which can be used effectively during the various learning stages.

During the first stage, relatively simple classroom demonstrators and other training aids are very effective. During the second stage inexpensive mock-ups can be effective. However, during both these two stages actual equipment trainers are apt to be used because they are available.

During the third stage of learning simulators can be very effective. Troubleshooting logic trainers or simulators are especially useful to teach the logical skills required to isolate malfunctions. Simulators also can be used effectively to provide practice on various skills. For example, a simulator of the cockpit, wings and undercarriage of an aircraft can be used to teach students to attach weapons to the aircraft. With rare exceptions, however, actual equipment trainers are used now to support the third stage of learning. Sometimes these have been modified locally to make them more effective as trainers.

Finally, on-the-job training usually is supported by operational equipment, but actual equipment trainers may be employed also. Whole-task simulators or trainers may be employed when it is not feasible to practice on the real equipment. For example, elaborate whole-task simulators are used to provide practice on the operation and maintenance of missile systems.

The point of all this discussion is that during the first three stages of learning training devices which are much less expensive than actual equipment trainers can be used effectively. As one approaches the fourth stage of learning the training devices must be more realistic. For example, simple mock-ups can be used during the second learning stage; more sophisticated simulators should be used during the third stage of learning. During the fourth stage of learning actual equipment trainers or operational equipment should be employed. When this is not possible, high fidelity simulators are required.

In closing this briefing, I would like to emphasize a second important point. The training device usage strategy which we are proposing here does not eliminate the use of real equipment for training. Rather, it attempts to use low cost, low fidelity devices whenever possible in order to better prepare students to profit from practice on more expensive trainers and real equipment. For example, suppose a course used three

or four expensive actual equipment trainers. We would propose that one or two of these not be used, and the money saved be spent on buying simulators, mock-ups, and other low-cost training aids and devices. The mock-ups would be used to prepare students to train on the simulators; the simulators would be used to prepare students to train on or work on real equipment. The purpose of low-cost, low fidelity training equipment is to prepare students so that they can rapidly master skills on more expensive equipment. This is the cost-effective way to use training devices.

Table II. General Relationship Between Stages of Learning, Training Sites, and Training Objectives

STAGES OF LEARNING	TRAINING SITE	GENERAL TRAINING OBJECTIVES
Novice		
1st Stage	School	Acquire Enabling Knowledges & Skills -- learn names & locations -- become familiar with job requirements -- become familiar with job content
2nd Stage	School	Acquire Uncoordinated Skills and Applicable Knowledges -- learn basic procedures -- learn part-task performance -- learn theory
3rd Stage	School	Acquire Coordinated Skills and Ability to Apply Knowledges -- practice procedures -- practice part-task performance -- practice conceptual skills, such as malfunction location -- practice application of theory
Apprentice		
4th Stage	Job	Acquire Acceptable Job Proficiency -- practice on the job -- participate in on-the-job training
Journeyman		

SLIDE I

Table III. General Relationship Between Stages of Learning, Training Objectives and Types of Training Devices

STAGES OF LEARNING	GENERAL TRAINING OBJECTIVES	TYPES OF TRAINING DEVICES
1st Stage ↓	Acquire enabling skills and knowledges	Demonstrators -- wall charts, films, TV, mock-ups, etc. Nomenclature & Parts Location Trainers
2nd Stage ↓	Acquire uncoordinated skills and unapplied knowledges	Part-task Trainers--AETs or Mock-ups Procedures Trainers--AETs or Mock-ups
3rd Stage ↓	Acquire coordinated skills and ability to apply knowledges	Troubleshooting Logic Trainers--Simulators Job Segment Trainers-- AETs or Simulators Skills Trainers--AETs or Simulators
4th Stage	Acquire job proficiency in job setting	Operational Equipment Actual Equipment Trainers Whole-Task Simulators

SLIDE II

RESULTS AND DISCUSSION

Questionnaire A--Media Usage Survey

Survey Findings

Questionnaire A was used to obtain the opinions of instructors regarding the use of low and medium cost and fidelity training devices and simulators. A copy of the questionnaire containing a summary of the responses to the multiple-option questions is located in Appendix A. Parts I and II of Questionnaire A were completed for 56 and 44 courses, respectively. Appendix D contains a summary of the responses provided to the open-ended questions. Appendices E and F contain two other sets of comments provided in response to some of the questions contained in the questionnaire.

Salient findings based on Questionnaire A data have been summarized in Table IV. Three general conclusions can be drawn from these findings:

1. In most courses actual equipment trainers were used (Section VII, Q-1) and instructors preferred it that way (Section VII, Q-2c) even though 26 percent reported that AETs tended to be unreliable (Section VII, Q-2b).

2. Most instructors expressed a willingness to use less expensive training devices and media if they were provided with them (Section I, Q-5) and if they were convinced of the effectiveness of those devices (Section VII, Q-4c, d, e).

3. Most instructors, regardless of the type of equipment covered in their course or the level of maintenance taught during the course, answered the questionnaire in a similar manner.

Table I (Page 6) shows the classification by type of equipment of the courses surveyed during this study. It can be seen that most of the courses taught maintenance of electronic equipment (n=49) while the second largest group of courses related to electro-mechanical equipment (n=24). A summary of the major differences in instructor responses based on type of equipment taught in a course is contained in Table V. Data are presented for only those questions which seemed

Table IV. Summary of Instructor Opinions About the Use of Various Training Devices and Media for Maintenance Training (Questionnaire A)

Part I

Section I--Use of Classroom Demonstrators

Q-1 82% prefer to use real equipment to demonstrate equipment operation, but other media used also
Q-2 89% do not use mock-ups, cut-aways, or animated panels which could be replaced by less expensive media
Q-3 75% agree that charts and transparencies can replace non-operating mock-ups
Q-4 70% agree that cut-aways, wall charts, etc. can substitute for cut-aways of AETs, or full-scale mock-ups
Q-5 80% would be willing to use less expensive training devices if evidence shows they are effective
Q-6 91% provide students with information about the context of various maintenance jobs

Section II--Use of Nomenclature and Parts Location Trainers

Q-1 70% teach nomenclature before students start using tools or working with parts
Q-2 66% use entire equipment to teach nomenclature. A similar percentage use training aids & equipment parts
Q-3 75% teach nomenclature by starting with the big picture and working down to detailed parts
Q-4 73% use AET to teach parts location. 53% also use wall charts, transparencies and/or slides
Q-5 71% would use packaged material to teach nomenclature and/or parts location.
Q-6 65% believed that students need to touch and feel real parts & tools; that seeing graphics isn't enough
Q-7 93% felt that nomenclature should be learned on the job
Q-8 98% felt that parts location should be learned in the job context
Q-9 66% reported that nomenclature and parts location cannot be learned from manuals alone

Section III--Use of Cue Discrimination Trainers

Q1a 45% use AETs to teach visual cue identification
Q1b 30% use AETs to teach aural cue identification. 28% reported aural cues are not relevant to the job
Q1c 23% reported that the detection of odors was not relevant to the job
Q1d 27% use torque wrench to teach feel of properly torqued nut. 21% reported this not relevant to the job
Q-2 71% of respondents said it is valuable to teach recognition of job odors and sounds
Q-3 77% reported that they would not use auditory tapes to teach sounds even if tapes were provided
Q-4 54% reported they would not use containers of odors to teach names of job-related odors. (Comments provided to Q-3 and Q-4 suggested that for many maintenance job odors and sounds are not relevant.)
Q5a 43% reported the use of AETs to teach visual discrimination
Q5b 38% reported the use of AETs to teach the difference between normal and abnormal equipment sounds
Q5c 43% said they do not teach odor discrimination
Q6a 52% reported the use of AETs to show the results of a maintenance action
Q6b 36% use AETs to show what equipment parts look like before and after maintenance action
Q7a 73% saw some value in providing graphics which show the result on equipment of maintenance actions
Q7b 77% saw some value in using graphics to show what parts look like before and after maintenance actions
Q-8 45% said mechanics need not memorize the difference between good and bad equipment conditions if these conditions are adequately described in TOs.

Table IV (Cont'd)

Part I (Continued)

Section IV--Use of Part Task Trainers (PTT)

Q-1 Few answered this question. Those who did listed what appeared to be an AET
Q2a 29% said they liked PTTs because they are AETs and students can work on real equipment
Q2b 11% said PTTs did not resemble real equipment; 9% complained about too much maintenance
Q-3 55% said they probably would use PTTs if they were available
Q-4 41% said they used PTTs less than 10% in the course

Part II

Section V-A--Use of Troubleshooting Logic Trainers: System Specific

Q-1 43% listed some type of system specific trainer as being used in their course
Q-2 44% reported a preference for using AETs; 37% preferred a mix of AETs and troubleshooting trainers
Q-3 81% teach use of TOs when teaching troubleshooting techniques
Q-4 10% said TOs do not contain enough detail: an additional 33% said TOs sometimes need more detail
Q-5 42% said troubleshooting should be taught on AETs; 53% agreed that trainers could be used to teach troubleshooting if that training was capped with training on an AET.
Q6a No consensus as to what strong points of troubleshooting logic trainers are
Q6b No consensus regarding disadvantages of troubleshooting logic trainers.
Q-7 58% reported they would or probably would use troubleshooting logic trainers if available

Section V-B--Use of Troubleshooting Logic Trainers: General Purpose Trainers

Q-1 40% said they were familiar with general purpose trainers
Q-2 63% reported they did not use general purpose trainers
Q-3 40% said they preferred systems specific trainers as opposed to general purpose trainers; 23% said they did not have enough information to make a choice
Q4a No consensus regarding strong points of general purpose trainers
Q4b No consensus regarding disadvantages to general purpose trainers
Q-5 33% reported they would like to devote 20-30% of their course to troubleshooting. An additional 37% would like to devote 30% or more of the course to troubleshooting.

Section VI--Use of Job Segment Trainers and Simulators

Q-1 63% report that they do not use job segment trainers or simulators
Q2a 14% liked the low cost and easy maintenance of trainers/simulators; 12% liked ability to miniaturize entire system and thus show student a complete system.
Q2b No consensus regarding "dislikes" for job segment trainers and simulators; few persons responded
Q2c Few instructors responded to this question
Q-3 No answers provided to this question.

Table IV (Cont'd)

Part II (Continued)

Section VII--Use of Actual Equipment Trainers (AET) and Operational Equipment

Q-1 74% reported that they make extensive use of AETs
Q2a 56% said they liked the realism of AETs
Q2b 26% complained that AETs cannot take wear and tear and thus tend to be unreliable
Q2c 60% said they preferred to use AETs as opposed to other types of training devices
Q-3 60% reported using AETs 80 or more hours during their course
Q-4 41% disagreed or expressed strong doubts about using other types of trainers instead of AETs
25% expressed a willingness to use low cost trainers but said more research is needed
34% were in favor of using low cost trainers when appropriate instead of AETs

most apt to reveal differences. Because of the small numbers involved, the "other" category of equipment is composed of precision/measuring, electrical/telecommunications, engines (aircraft), hydraulic, and miscellaneous equipments. The salient findings of the foregoing analysis were as follows:

1. Most instructors responded similarly despite differences in type of equipment covered during their course.

2. Instructors of electronic courses were:

   a. more willing to use less expensive trainers (Sec. I, Q-5)
   b. more willing to use part task trainers (Sec. IV, Q-3)
   c. more in favor of using low cost/fidelity trainers (Sec. VII, Q-4c)
   d. more apt to use expensive AETs (Sec. VII, Q-4a)

3. Instructors of electro-mechanical courses were:

   a. more interested in the use of systems specific trainers (Sec. VA, Q-7)
   b. more apt to employ job segment trainers (Sec. VI, Q-1)

4. Instructors of non-electronic/non-electromechanical courses were:

   a. least willing to use inexpensive training devices (Sec. I, Q-5)
   b. most willing to use packaged training material (Sec. II, Q-5)
   c. most apt to employ part-task trainers (Sec. IV, Q-1)
   d. most apt to prefer AETs (Sec. VA, Q-2; Q-5)
   e. most apt to use general purpose troubleshooting logic trainers (Sec. V-B, Q-2)
   f. most apt to favor use of AETs over low cost/fidelity trainers (Sec. VII, Q-4a and 4e).

At resident technical training centers maintenance courses are taught at three different levels: the 3-, the 5- and the 7-levels. The 3-level courses are introductory or basic maintenance courses. Graduates of these courses are not expected to possess troubleshooting skills or a high degree of knowledge about various types of equipment. The 5- and 7-level maintenance courses are for experienced technicians. These courses emphasize troubleshooting skills and the supervision of

Table V. Response Differences Based on Type of Equipment and Level of Maintenance Covered in Course (Questionnaire A)

	Type of Equipment Covered in Course			Course Level	
	Electronic	Electro-Mechanical	Other	3-level	5- & 7-level
Part I					
Section I					
Q-1 Prefer use of AETs for demonstration	85%	93%	67%	83%	76%
Q-5 Willing to use less expensive training devices	85%	80%	54%	88%	57%
Section II					
Q-5 Willing to use packaged training material	70%	66%	80%	72%	71%
Section III					
Q-7b Saw value in showing results of maintenance on parts	91%	73%	80%	78%	71%
Section IV					
Q-1 Reported use of part-task trainers	50%	47%	80%	57%	43%
Q-3 Willing to use more part-task trainers	69%	40%	47%	66%	58%
Part II					
Section V-A					
Q-1 Reported use of system specific trainer	66%	33%	50%	45%	81%
Q-2 Reported preference for using AETs	34%	33%	67%	34%	72%
Q-2 Reported preference for using media mix	30%	56%	25%	16%	9%
Q-5 Reported preference for using AETs	52%	55%	75%	57%	82%
Q-7 Reported interest in using system specific trainers	52%	78%	34%	68%	36%

Table V. (Continued)

	Type of Equipment Covered in Course			Course Level	
	Electronic	Electro-Mechanical	Other	3-level	5- & 7-level
Part II (Continued)					
Section V-B					
Q-2 Reported use of general purpose troubleshooting logic trainer	34%	67%	83%	44%	18%
Q-3a Reported preference for system specific trainer	43%	33%	23%	28%	73%
Q-3b Reported preference for general purpose trainer	13%	--	25%	16%	9%
Section VI					
Q-1 Reported use of job segment trainer or simulator	23%	55%	33%	61%	64%
Section VII					
Q-1 Reported use of large, expensive AETs	91%	55%	33%	85%	82%
Q-4 Disagreed/doubtful about using other than AETs	25%	44%	75%	36%	54%
Q-4c Willing to see more research on use of low cost trainers	22%	33%	17%	24%	27%
Q-4 In favor of using low cost/fidelity trainers	54%	22%	8%	39%	18%

less experienced mechanics. Because of the basic differences in course standards between 3-, 5- and 7-level courses, especially with respect to troubleshooting skills, it might be expected that instructors of 5/7-level courses would respond to Questionnaire A differently than would instructors of 3-level courses. Table V shows how these two groups of instructors responded on a selected group of questions. Relative to instructors of 5- and 7-level courses, instructors of 3-level maintenance courses:

1. were more willing to use less expensive trainers (Sec. I, Q-5)
2. were less apt to use system specific trainers (Sec. V-A, Q-1) but expressed more of an interest in using such trainers (Sec. V-A, Q-7).
3. expressed less preference for using AETs (Sec. V-A, Q-2, Q-5)
4. expressed less preference for system specific as opposed to general purpose troubleshooting trainers (Sec. V-B, Q-3)
5. were more in favor of using low cost/fidelity trainers (Sec. VII, Q-4).

The foregoing findings indicate that 5- and 7-level course instructors are more apt to favor the use of actual equipment trainers and/or specific equipment trainers.

Discussion

Most current and past research and applied efforts related to the development of maintenance simulators have concentrated on electronic equipment. (5) These R&D projects have shown that simulators can be effectively used to teach maintenance, especially the skills of troubleshooting. Other projects have demonstrated that low and medium cost/fidelity devices can be effective when teaching equipment operation, parts location, and the conceptual aspects of fault isolation. (2, 4, 14) In light of this past research, it is not surprising to find that instructors of electronic courses express a general willingness to use simulators and other forms of low to medium cost and fidelity trainers.

The next section of this report will discuss the identification of 36 equipments which seem prime candidates for simulation. Thirty-one of these equipments were identified by instructors known to be involved with or at least familiar with ongoing simulation projects at Lowry, Keesler and Chanute AFBs. This finding, and the survey finding that instructors of electronic courses tend to favor the use of simulators suggests that instructors favor the use of simulators

and lost cost and fidelity training devices to the extent that they are familiar with these devices and have been directly exposed to the devices themselves or to instructors favorably disposed towards the devices.

The Use of Instructors as Information Sources. In the authors' opinion almost all of the data obtained through use of Questionnaire A can be easily understood in terms of commonly-held opinions of maintenance course instructors. As indicated by a number of the comments provided during this survey, maintenance course instructors prefer to teach both the theory and skills involved in equipment maintenance, and they prefer to accomplish this using what to them seems the best and most logical approach--the use of the actual equipment which eventually will be maintained by the student. For this reason, instructors (especially 5- and 7-level course instructors) prefer to use system specific as opposed to general purpose trainers.

Generally, instructors tend to be conservative in that they prefer to use proven instructional devices and techniques with which they are familiar. They will accept new training devices and techniques after considerable evidence has been collected regarding their effectiveness (see Table IV, Sec. VIII, Q-4c). As the need arises they do point out areas within their courses where extant training devices or techniques are ineffective. Then they may become involved in the development of new instructional devices or at least study up on other devices which may be available. This suggests that instructors may be good information sources with respect to the effectiveness of training devices and techniques but that they normally would not be good sources of information about where and under what conditions state-of-the-art training devices might be employed; in sum, they should not be the primary ones to decide on the implementation of simulators or other training devices.

Evaluation of Usefulness of Training Device Categories Used in Questionnaire A. During the initial development of Questionnaire A, an attempt was made to develop a taxonomy of training devices. It was hoped that this would enable us to make generalized statements about the study findings in terms of their applicability to various categories of training devices. This effort commences with a review of the literature, especially articles by G. G. Miller (9), R. B. Miller (10, 11) and Kinkade and Wheaton (8). As a result of this exploration into the literature we concluded that training device taxonomies are of limited value. A major problem with them is that different taxonomies can be developed for different purposes. Moreover, it is almost impossible to clearly delineate the boundaries between adjacent taxonomic categories. For example, many writers talk

about a category of Part-Task Trainers which is a term familiar to most instructors. However, with rare exceptions, almost all trainers fall into the category of part-task trainers since they are used to train something less than a complete maintenance task performance.

Some authors have attempted to categorize training devices and techniques in terms of the general categories of skills and knowledges they are best designed to teach. For example, training devices and techniques might be designed to teach: facts and definitions, concepts, principles, procedures, mental skills, psychomotor skills, and attitudes. The Air Force's 3306th Test and Evaluation Squadron during its ISD analysis, has found it useful to select training media in terms of these skill and knowledge categories.

For the purpose of developing a structure for Questionnaire A seven categories of training devices were established as follow:

- I Demonstrators
- II Nomenclature and Parts
- III Cue Discrimination Trainers
- IV Part-Task Trainers
- V Troubleshooting Logic Trainers
  - A. Systems Specific
  - B. General Purpose
- VI Job Segment Trainers and Simulators
- VII Actual Equipment Trainers and Operational Equipment

When adequately defined by means of examples the categories proved useful enough for the purpose of obtaining judgements about the effectiveness of various types of instructional media and training devices. The definition used for the term "simulator" was quite general and was similar to that developed by Gagne (see footnote, page 1).

To give the training device categories more meaning an instructor briefing was prepared which related each category of training device to one of four stages of learning. This "Stages of Learning" briefing has been discussed already. While preparing this briefing we related each category of trainer to a stage of learning which, according to the literature, could best be supported by that category of training device. In effect, the "Stages of Learning" briefing categorized trainers into four classes each related to a stage of learning as follow:

Stage I of Learning -- Familiarization trainers
Stage II of Learning -- "Acquisition of basic skills and knowledge" trainers
Stage III of Learning -- "Refinement of skills and knowledge in the training setting" trainers
Stage IV of Learning -- "Transfer of training to the job setting" trainers

Evaluation of the Usefulness of Questionnaire A

Questionnaire A provided a variety of information about training devices which currently are employed in maintenance courses. This information served to document anecdotal evidence about the use of training devices, and especially about the use of actual equipment trainers. This information, however, did not provide much help towards identifying the courses where maintenance simulators might effectively be employed. The survey data could be used to identify courses where the resistance to simulators would be slight or extensive. If one is interested in identifying instructor attitudes, opinions, and usage patterns related to maintenance training equipment, then the administration of Questionnaire A on a three-five year interval would be useful. If one is interested in identifying equipments which might be replaced by simulators then Questionnaire B, Part II (to be discussed) should be employed.

Questionnaire B, Part I--Major Problem Areas with Training Equipment

Survey Findings

The purpose of Part I of Questionnaire B was to obtain information about some of the problem areas commonly associated with training equipment. A copy of the questionnaire containing a summary of the responses is located in Appendix B. Appendix G contains a listing of the comments provided by the respondents.

A summary of the findings for Questionnaire B, Part I is contained in Table VI. A perusal of these findings suggests that most instructors were satisfied with the training equipment available to them. They reported that:

1. they had sufficient numbers of trainers
2. the trainers were adequate for doing the training job
3. they usually could use the equipment when they wanted to
4. use of the trainers had not been constrained due to cost considerations
5. they had not been constrained from making modifications to training equipment
6. critical course areas were adequately supported by training equipment.

Only 43% of the instructors judged their trainers to be reliable (Q-6). As discussed later on, it seems to be the factor of training equipment unreliability which eventually forces instructors to consider alternatives to actual equipment trainers.

Table VII contains a break-out of the responses to Questionnaire B, Part I in terms of equipment covered in course and level of maintenance taught during course. Of most interest is the finding that instructors of electronic equipment courses are less apt to judge their equipment to be reliable (Q-6) than are instructors for other types of equipment. Also, electronic equipment instructors are less apt to report having adequate numbers of training devices (Q-1); more apt to report that equipment is not available for training (Q-3); and more apt to report that they have been constrained from modifying their training equipment (Q-5). All these findings are very understandable. Comparatively speaking, electronic equipment malfunctions more often than other types of equipment. This makes it unavailable for training (Q-3). One way to offset this problem is to obtain more equipment (Q-1).

Table VI. Summary of Responses to Questionnaire B
Part I: Major Problem Areas Concerning Training Equipment

Q-1 85% reported they had sufficient numbers of training equipment

Q-2 81% reported that their training equipment was adequate

Q-3 74% reported that training equipment usually was available for training

Q-4 92% said their use of training equipment had not been constrained by equipment cost

Q-5 80% said they had not been constrained from making or requesting modifications to training equipment

Q-6 43% judged their trainers to be reliable; 37% said their trainers were of average reliability; 18% said their trainers were not reliable

Q-7 79% reported that, in their opinion, critical training areas were properly supported by training equipment

The problem of training equipment reliability is of more concern to instructors of 5- and 7-level courses than to instructors of 3-level courses (see Q-6 and Q-7). The 5- and 7-level courses concentrate on teaching maintenance skills, especially fault isolation, and on providing hands-on experience. Therefore, it is essential to support these courses with either actual equipment trainers or a variety of simulators and part-task trainers.

Evaluation of the Usefulness of Questionnaire B, Part I

After reviewing the results obtained through the use of Questionnaire B, Part I, the authors concluded that the data obtained provided little information of interest about training problems. Moreover, the data did not help identify areas where simulators might be employed. In addition, the data obtained on Part I of the questionnaire sometimes was at variance with that provided for Part II of the questionnaire. For example, in Part I a respondent might report that he had sufficient numbers of trainers, while in Part II he might indicate a need for additional actual equipment trainers. Finally, some of the questions contained in Part I duplicate those contained in Part II. Therefore, it seems appropriate that Parts I and II of Questionnaire B should be combined into a single questionnaire for any future use of this survey instrument.

Table VII. Response Differences Based on Type of Equipment and Level of Maintenance Covered in Course

	Type of Equipment Covered in Course			Course Level	
	Electronic	Electro-Mechanical	Other	3-level	5- & 7-level
Part I					
Q-1 Had sufficient numbers of training equipment	75%	91%	89%	83%	79%
Q-2 Judged training equipment to be adequate	79%	87%	85%	80%	83%
Q-3 Reported training equipment as usually being available	64%	87%	89%	74%	75%
Q-4 Use of trainers not constrained by cost considerations	88%	100%	96%	91%	96%
Q-5 Had not been constrained from making or requesting modifications to training equipment	69%	87%	93%	78%	88%
Q-6 Judged their training equipment to be reliable	31%	56%	52%	45%	38%
Q-7 Said critical training areas adequately supported by training equipment	75%	87%	74%	82%	71%

Questionnaire B, Part II--Identification of Actual Equipment Trainers which Might Be Simulated

Survey Findings

The purpose of Part II of Questionnaire B, was to identify high cost actual equipment trainers which might be replaced in whole or in part by simulators. Through the use of this Questionnaire, 80 actual equipment trainers were identified which had a unit cost of $100,000 or more. These 80 trainers are listed in Table VIII along with a variety of information about each trainer. This information is as follows:

1. A course number and the location of that course is listed on the left of the Table.

2. Under "Course name and name of trainers" are listed the name of the course and all trainers used in that course which have an approximate unit cost of $100,000 or more.

3. The approximate unit cost for each listed trainer is shown to the immediate right of the name of each trainer (Column c).

4. Under Column d, "Unscheduled Maintenance July 76 through June 77" has been listed the number of hours of unscheduled maintenance performed on the trainer for a 12-month period. In a few cases a thousand or more hours of unscheduled maintenance was reported. With rare exceptions that meant that the trainer was down for maintenance because of a lack of spare parts.

5. Under Column 3, "Approximate Age of Trainer" is listed the approximate number of years that the trainer has been at a technical training center.

6. Column f contains the responses provided to Question One, Parts a through f of Questionnaire B, Part II. For example, Question 1.a. asks the question "Is this AET effective?" The response options were 1, 2, 3 and 4. 1 means "definitely yes;" 4 means "definitely not"; 2 means "maybe yes;" and 3 means "maybe no." The six subparts to Question 1 all relate to whether or not the trainer is effective for teaching troubleshooting. For a highly effective trainer the response of "1" would be provided to all parts of Question 1. For a very ineffective trainer responses of 3 or 4 would be provided to most, if not all parts of Question 1. An instructor might judge a trainer to be highly effective yet also judge it to be unreliable, difficult to maintain and hard for students to use. Two of the test sets listed at the bottom of the first page of Table VIII are examples of this type of trainer.

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Table VIII. List of Trainers Costing $100,000.00 or r More and Which May be Candidates for Simulation

Course No. (a)	Course Name and Name(s) of Trainer(s) (b)	Approx. Unit Cost (c)	Unscheduled Maint. July 76 through June 77 (d)	Approx. Age of Trainer (e)	Responses To Questionnaire B, Part II: Q-1 a b c d e f (f)	Q-2 (g)	Q-3 (h)	Q-4 a b c (i)	Simulation Potential Ranking (j)
G3ABR32131G (Lowry)	Defensive Fire Control Mechanic (MD-9,ASG-15 Turrets)								
	a. ASG-15 Wpns Control System Trainer	267K	?	17 Yrs.	1 2 3 2 2 1	3	3	2 4 4	6
3ABR32132N (Lowry)	F-105 Weapons Control System, R-14A Radar								
	a. R-14A Radar Trainer	100	63 Hrs	17	1 2 2 2 2 3	2	4	2 2 3	7
3ABR32131E (Lowry)	Defensive Fire Control System Mechanic, ASG-21								
	a. Control Time Platform Test Set	142	191	17	1 1 1 1 1 1	2	4	4 4 4	5
	b. Antenna Test Set	122	531	17	1 1 1 1 1 1	1	4	4 4 4	6
	c. Frequency Converter Transmitter Test Set	96	237	17	1 1 1 1 1 1	1	4	4 4 4	5
	d. Ballistics Computer Test Set	173	371	17	1 1 1 1 1 1	1	4	4 4 4	6
	e. Tracking Control Assembly Test Set	122	305	17	1 1 1 1 1 1	1	4	4 4 4	5
	f. Control Indicator Test Set	125	367	17	1 1 1 1 1 1	1	4	4 4 4	6
3AZR32150K-1 (Lowry)	Electro-Optical Viewing System AGE Technician, B52 G/H								
	a. Electro-Optical Viewing Test Set, EVS-017	110	172	4	2 4 4 2 2 2	2	3	2 2 2	9
	b. Electro-Optical Viewing Test Set, EVS-018	551	515	4	3 2 2 4 4 4	2	4	3 3 3	9
G3ABR32130K (Lowry)	Bombing Navigation System Technician								
	a. ASB-9A Bomb-Nav. System	231	371	18	1 2 3 1 1 1	3	4	4 4 4	7
	b. ASQ-151 Electro-Optical Viewing System	?	218	1	1 1 1 1 1 1	1	2	4 4 4	-
	c. ASB-15 Bomb-Nav. System	?	571	?	1 2 3 1 1 1	3	4	4 4 4	-
3ABR32232B (Lowry)	Avionics Sensor System Specialist (Tactical/Real Time Di:splay Elec. Sensor)								
	a. AN/AAD-7 Forward Looking Infra-Red System	74	618	3	2 4 3 3 3 2	1	1	2 2 4	8
	b. AN/ASQ-153 Electro-Optical Target Designator/Rangeir	318	873	6	2 2 4 3 3 2	2	1	2 2 4	9
G3ALR32152C (Lowry)	Weapons Control System Mechanic (F100 A/B. MA-1. ASQ-25 (Subsystems)								
	a. MA-1 Wpns Control System Test Stands	255	1700	4	1 2 3 2 2 3	1	2	2 4 4	9
3ABR32631E (Lowry)	Integrated Avionics Components Specialists (AGE, etc. for FB-111, etc.)								
	a. 12A96811 Test Set	399	6654	8	2 4 4 4 4 2	1	3	3 3 3	10
	b. 12A16891 Test Set	484	?	8	2 3 4 3 3 3	1	3	3 3 3	7
	c. 12A16812 Test Set	197	832	8	2 2 2 2 2 2	1	4	4 4 2	9
3ABR32630B	Avionics Aerospace Ground Equip. Specialist (Auto Av. AGE, F-111 A/E)								
	a. 12A6830 Test Set	349	77	7	1 4 4 4 4 2	3	4	2 4 4	8
	b. 12A16802 Receiver-Transmitter Modulator Test Set	465	58	1	1 4 4 4 4 1	1	1	2 2 4	8
	c. 12A16803 Computer Test Set	441	44	1	2 3 4 3 3 2	1	2	3 3 2	8
	d. 12A6886 Electronic Systems Test Set	285	2063	3	2 3 3 3 2 3	1	2	2 2 3	9
	e. 12A1803A1 CADC Test Station	124	923	7	2 2 3 2 2 2	1	2	3 3 2	9
	f. 12A6895 Servo and Indicator Test Set	181	412	7	2 3 4 3 3 2	1	2	3 3 2	9

Table VIII. (Continued)

Course No. (a)	Course Name and Name(s) of Trainer(s) (b)	Approx. Unit Cost (c)	Unscheduled Maint. July 76 through June 77 (d)	Approx. Age of Trainer (e)	Responses To Questionnaire B, Part II: Q-1 a b c d e f (f)	Q-2 (g)	Q-3 (h)	Q-4 a b c (i)	Simulation Potential Ranking (j)
3ABR32631D (Lowry)	Integrated Avionics Components Specialist								
	a. 12A6863 Test Set	435K	798 Hrs	6 Yrs	2 3 4 3 2 4	1	4	2 2 2	10
G3ABR32630B (Lowry)	Avionics Aerospace Ground Equipment Specialist								
	a. 12A6883 Test Set	440	2019	3	2 3 4 4 3 4	1	4	1 1 4	11
	b. 12A6885 Test Set	390	2227	3	2 3 4 4 3 4	1	4	1 1 4	11
	c. 12A6882 Test Set	1000	569	3	2 3 4 4 3 4	1	4	1 1 4	10
	d. 12A6887 Test Set	880	150	?	2 3 4 4 3 4	1	4	1 1 4	10
G3AZR46350-1 (Lowry)	Nuclear Weapons Specialists, Minuteman III								
	a. UB Trainer	1502	147	?	1 1 1 1 1 2	2	4	4 4 4	7
	b. Grouped AGE	500	34	?	1 1 3 2 1 2	1	4	4 4 4	6
3ABR32232A	Avionics Sensor Systems (Recon.)								
	a. AN/AWM-17.	171	?	11	1 1 1 1 1 2	2	4	4 4 4	4
	b. LT-56.	970	4377	5	1 1 3 2 1 2	1	4	4 4 4	9
3AZR30372-4 (Keesler)	AN/FPS-26A Radar Maintenance								
	a. AN/FPS-26A	850	630	15	2 2 4 2 1 2	1	4	1 4 4	9
3AZR30372-12 (Keesler)	AN/FPS-66A O-I Maintenance								
	a. AN/FPS-66A Radar	800	49	25	1 2 2 2 2 2	4	3	3 4 4	7
3AZR30454-6 (Keesler)	Ground Radio Communication Equipment Repairman (AN/FLR-9)								
	a. AN/FLR-9 Trainer	700	177	12	1 1 1 1 1 1	1	4	4 4 4	7
3ABR30332 (Keesler)	Aircraft Control and Warning Radar Repairman								
	a. AN/FPS-6	375	4	25	1 1 2 2 2 1	3	4	4 4 4	5
	b. AN/FPS-90.	375	4	25	1 1 2 2 2 1	1	4	4 4 4	5
3ABR30333 (Keesler)	Automatic Tracking Radar Repairman								
	a. AN/MSQ-77, Radar Bomb Directing Central Trainer.	800	1280	25	2 2 2 2 2 2	2	4	2 2 4	10
	b. AN/TSQ-81, Radar Bomb Directing Central Trainer.	900	2095	25	2 2 2 2 2 2	1	4	2 2 2	11
3ABR30331 (Keesler)	Air Traffic Control Radar Repairman								
	a. AN/MPN-13.	1624	1373	25	1 2 2 2 2 1	4	4	1 4 4	10
	b. AN/FPN-47.	230	1246	12	1 1 2 1 1 3	2	4	1 4 4	9
	c. AN/TPX-42.	125	300	6	1 1 3 3 3 3	9	4	1 4 4	9

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Table VIII. (Continued)

Course No. (a)	Course Name and Names(s) of Trainer(s) (b)	Approx. Unit Cost (c)	Unscheduled Maint. July 76 through June 77 (d)	Approx. Age of Trainer (e)	Responses To Questionnaire B, Part II: Q-1 a b c d e f (f)	Q-2 (g)	Q-3 (h)	Q-4 a b c (i)	Simulation Potential Ranking (j)
3ABR30534 (Keesler)	Elevtronic Computer Systems Repairman								
	a. AN/GSA-51 Computer System (BUIC)	2400K	148 Hrs	15 Yrs	1 2 2 1 1 1	1	4	4 4 4	8
3AZR30454-15 (Keesler)	AN/TSC-60 Communication Central O/I Maintenance								
	a. AN/TSC-60	300	182	5	2 2 2 2 1 2	2	4	3 3 4	7
3ABR30534-7 (Keesler)	Electronic Computer Systems Specialist								
	a. AN/TSQ-91	3200	2007	5	1 1 1 1 1 1	2	3	3 3 3	9
3ALR32850A-1 (Keesler)	Airborne Command Post CE Repairman								
	a. ARC-96 TX (Test Set) & ARC-96 RX	666	190	10	1 1 2 2 1 1	1	4	2 2 4	8
3ABR31632F (Sheppard)	Missile Electronic Equipment Specialist								
	a. Trainer QD, Launch, Control, Monitor & Checkout	751	155	16	1 2 3 2 1 1	2	3	4 4 4	7
	b. Trainer QA, Missile Handling and Installation	237	99	15	1 1 1 1 1 1	1	4	4 4 4	6
	c. Trainer QE, Flight Control Systems	676	54	16	1 2 2 1 1 1	1	4	4 4 4	6
	d. Trainer QB, Missile Stages Inspection	187	217	15	1 3 3 1 1 1	1	2	4 4 4	6
	e. Trainer QF, Missile Electrical System	518	19	15	1 3 3 1 1 1	1	4	4 4 4	6
3ABR31631F (Sheppard)	Missile Systems Maintenance Specialist								
	a. Trainer GA & GD, Inertial Guidance System	1000	103	16	1 1 1 1 1 1	1	4	4 4 4	7
	b. Trainer GC, Inertial Guidance System Equipment Group	1000	7	16	1 1 1 1 1 1	1	4	1 4 4	7
3ABR36233 (Sheppard)	Missile Control Communication Systems Specialist								
	a. Trainer EB, Titan II Missile Communication System	500	290	13	1 2 2 2 1 1	1	4	1 4 4	9
	b. Trainer EC, Minuteman Missile Communication System	593	388	11	1 2 2 1 1 1	1	4	1 4 4	9
3AZR43170-2 (Sheppard)	Helicopter Mechanic								
	a. UH-1F Helicopter Composit Trainer	192	139	11	1 2 2 2 2 3	1	2	2 3 4	7
3ABR43130 (Sheppard)	Helicopter Mechanic								
	a. UH-1N Helicopter Composite Trainer	600	370	7	1 1 1 1 1 4	1	1	3 4 4	7
3ABR31630G-4 (Chanute)	Missile System Analyst Specialist, WS-133B/CDB								
	a. LF Electrical Power/Air Conditioning System Trainer	500	332	1	1 1 1 1 1 1	1	3	4 4 4	7
3ABR31632G-1 (Chanute)	Missile Electronic Equipment Specialist, WS-133A-M								
	a. AN/GSM-82, Electronic Facility Base Maint. Test Equip.	500	-	17	1 1 1 1 1 1	1	4	4 4 4	5
	b. AB/UYM-3, Computer Test Set & Digital Data Computer Set	1250	146	6	2 3 3 3 3 4	1	3	2 2 4	9
	c. AB/GSM-234 Memory Controller Group T/S & OL-90	325	-	6	2 2 2 2 2 3	1	4	2 2 4	7
	d. AN/GSM-260 Guided Missile Test Station	1800	30	1	1 2 3 3 1 2	2	4	3 3 4	8
3ABR31630G-4 (Chanute)	Missile System Analyst Specialist, WS-133/CDB								
	a. Integrated Ground Electronic Equipment Trainer	450	-	2	1 1 1 1 1 1	1	3	4 4 4	5

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Table VIII. (Continued)

Course No. (a)	Course Name and Name(s) of Trainer(s) (b)	Approx. Unit Cost (c)	Unscheduled Maint. July 76 through June 77 (d)	Approx. Age of Trainer (e)	Responses To Questionnaire B, Part II: Q-1 a b c d e f (f)	Q-2 (g)	Q-3 (h)	Q-4 a b c (i)	Simulation Potential Ranking (j)
3ABR31630T (Chanute)	Airborne Missile System Analyst (AGM-69A)								
	a. T-34 Avionic Guided Missile Training Set (Msl)	1960K	4 Hrs	7	1 2 2 1 1 1	2	4	4 4 4	6
	b. T-34 Avionic Guided Missile Training Set (Support Equip)	1182	18	7	1 2 2 1 1 1	2	4	4 4 4	6
	c. T-35 B-52/AGM-69 Trainer	420	7	7	1 1 1 1 1 1	4	4	4 4 4	5
	d. T-36 FB-111/AGM-69A Trainer	332	6	7	1 1 1 1 1 1	2	4	4 4 4	5
3AZR31670G-6 (Chanute)	Technical Engineering Analysis Team (Missiles)								
	a. WS-133A, AN/GMS-T3(OD) Missile System Launch Control Trainer	8800	270	5	1 2 2 1 1 2	1	3	4 4 4	9
3ABR34135 (Chanute)	Analog Navigation/Tactics Training Device Specialist								
	a. AN/GPO-T10	580	402	22	3 3 2 3 2 3	2	4	4 1 4	10
3ABR42330 (Chanute)	Aircraft Electrical Systems Specialist								
	a. CT-43 AC Power System	200	57	1	3 2 2 3 3 3	6	2	4 4 3	9
3ABR34134 (Chanute)	Digital Flight Simulator Specialist								
	a. Digital Maintenance Part Task Trainer	300	616	1	3 4 4 4 4 4	1	1	1 1 3	10
3AAR42371 (Chanute)	Aircraft Environmental Systems								
	a. C-5 Air Conditioning & Pressurization Trainer	261	66	6	2 2 2 2 2 4	1	3	3 3 4	7
3ABR42334 (Chanute)	Aircraft Pneudraulic System Mechanic								
	a. Primary Flight Control Trainer, 4458	185	42	2	1 1 4 1 1 4	1	4	1 4 4	7
3ABR42333 (Chanute)	Aircraft Fuel System Mechanic								
	a. CT-40 Fuel System (F-4d)	103	67	10	1 1 1 1 1 1	1	4	3 4 4	5
3ABR32531 (Chanute)	Avionics Instrument System Specialist								
	a. Central Air Data Computer Trainer (F-4)	125	-	9	2 3 3 2 2 2	3	4	3 3 3	6
3ABR32530-1 (Chanute)	Automatic Flight Control System Specialist								
	a. A/A42G-11 Autopilot Trainer	148	36	15	1 2 2 1 1 1	5	1	2 4 4	6
	b. FB-111 AFCS Trainer	195	50	6	2 3 3 2 2 2	2	3	2 4 4	7
	c. F-111A AFCS Trainer	160	36	8	2 3 3 2 2 2	2	3	2 4 4	6

7. Under "Q-2", Column g, is listed the number of actual equipment trainers now used in a course. The significance of this number is that it is more practical to use simulators in courses which currently employ two or more AETs--the simulator can replace one or two AETs.

8. Under the Column h, has been listed the answers to Question 3, "Do you need more AETs?" An answer of 1 means "yes," an answer of "4" means "definitely no."

9. Under the column entitled "Q-4" (Column i) has been listed the responses to three questions--"Could you use Simulators in Addition to AETs (Q-4a); Could you use Simulators to Replace some AETs (Q-4b); and Could you use Simulators to Replace All AETs (Q-4c)?" For the three parts of Question 4, a response pattern of three 4s is an indication of a complete rejection of the use of simulators. A complete acceptance of simulators would be indicated by a 1-1-1 or a 4-4-1 pattern of responses. In this survey the most positive pattern of responses for Question 4 was 2-2-2 which was obtained for the ninth trainer listed on Page 1 of Table VIII. This same pattern was obtained for two other trainers.

10. The column labeled "Simulation Potential" contains a number which represents the potential for or advantages to be gained by simulating a particular trainer <u>relative to the other trainers</u> listed in Table VIII. The procedure by which this number was derived is explained in Appendix H. Essentially, this number is a rank which is based on the sum of 4 ranks based respectively on: the unit cost of the trainer, the amount of unscheduled maintenance, the effectiveness of the trainer for teaching troubleshooting (sum of the answers to all parts of Question 1); and rankings based on the pattern of responses to Question 4 (the pattern 4-4-4 received a rank of 1, while the rank of 1-1-1 received a rank of 15. Other possible patterns were ranked according to the degree to which they supported the notion of using simulators to replace all actual equipment trainers (see Appendix H).

On Table VIII the Simulation Potential ranks vary from 1 to 8. Those trainers receiving a simulation potential rank of 1 (3 in number) are those which, according to the respondents, are the best candidates for replacement by simulators. Eight other trainers received a simulation potential rank of 2; these have been considered

next or second in priority with respect to their potential for being replaced by simulators. A third group of 18 trainers, those which received a simulation potential rank of 3, have been classified as third priority trainers with respect to their potential for being replaced by simulators. Seven additional AETs were classified as "4th Priority" trainers. This information, involving a total of 36 trainers, is summarized in Table IX. Table IX lists the 36 trainers in terms of first, second, third, or fourth priority trainers for simulation. For each trainer the reasons for considering simulation instead of the actual equipment trainer have been listed.

Table X classifies the "high simulation potential" trainers in terms of type of equipment. The points to note with respect to this table are: 14 trainers were test sets or benches, most of which are used to check out line replaceable units. Eight other high priority candidates for simulation were radar sets. This list of high priority candidates for simulation contains no trainers which could be classified as strictly mechanical or even electromechanical trainers. Moreover, of the 36 high priority candidates for simulation, 32 were AETs which are electronic in nature. Three others involved electro-optical equipment; only one trainer pertained primarily to electrical equipment--the CT-43 AC power system.

Discussion

Validity of Data Used to Calculate Simulation Potential. The data displayed in Table VIII are from the most reliable sources available, e.g., Consolidated Maintenance Squadron records. However, their absolute validity is questionable.

1. Unit Cost of Training Equipment. The unit cost of training equipment was determined by consulting the Custodial Receipt Listing maintained by a Technical Training Group. This listing will not record costs above $999,999.00, however. To determine the unit cost of very expensive equipment it is necessary to consult other sources of information maintained by the equipment custodian.

Sometimes the listed unit cost of a trainer seemed much too low, e.g., $50,000 for a large electronic equipment trainer. To explain this we found that the cost of equipment may be reported in terms of the cost required to modify the equipment for training after it had been acquired by the school. In such instances other data sources, usually letter/memo files, maintained by the equipment custodian had to be consulted.

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Table IX. List of TTC Trainers Which Are Best Candidates for Simulation

Course No.	TTC	Name of Trainer	Reasons for Considering Simulation
1st Priority			
G3ABR32630B	Lowry	12A6883 Test Set	very high unscheduled maintenance; poor trainer; instructor wants
		12A6885 Test Set	very high unscheduled maintenance; poor trainer; instructor wants
3ABR30333	Keesler	AN/TSQ-81, Radar Bomb Directing Central	very high unscheduled maintenance; high unit cost; instructor wants
2nd Priority			
3ABR32631E	Lowry	12A96811 Test Set	high unscheduled maintenance, (instructor probably does not want)
G3ABR32630B	Lowry	12A6882 Test Set	very high unit cost; poor trainer; instructor wants
		12A6887 Test Set	high unscheduled maintenance; poor trainer; instructor wants
3ABR30333	Keesler	Radar Bomb Directing Central Trainer, MSQ-77	high unscheduled maintenance; instructor probably will accept
3ABR30331	Keesler	Air Traffic Control Radar, AN/MPN-13	very high unit cost; high unscheduled maintenance; instructor wants
3ABR34135	Chanute	AN/GPO-T10 (Analog Navigation/Tactics Training Device)	poor trainer; instructor wants
3ABR32631D	Lowry	12A6863 Test Set	poor trainer; instructor probably will accept
3ABR34134	Chanute	Digital Maintenance P.T.T. (Flight Simulator)	high unscheduled maintenance; instructor wants
3rd Priority			
3AZR32150K-1	Lowry	Electro-Optical Viewing Test Set, EVS-017	not a good trainer; instructor probably will accept
	Lowry	Electro-Optical Viewing Test Set, EVS-018	not a good trainer; instructor probably will accept
3ABR32232B	Lowry	Electro-Optical Target Designator/Ranger	high unscheduled maintenance; instructor might accept
G3ALR32152C	Lowry	MA-1 Weapons Control System Test Stand	very high unscheduled maintenance; instructor might accept
3ABR32630B	Lowry	12A6886 Electronic Systems Test Set	very high maintenance; poor trainer; instructor probably will accept
	Lowry	12A1803A1 CADC Test Set	high unscheduled maintenance; instructor probably will accept
	Lowry	12A6895 Servo and Indicator Test Set	poor trainer; instructor probably will accept
3ABR32631E	Lowry	12A16812 Test Set	high unscheduled maintenance; instructor probably will accept
3ABR32232A	Lowry	LT-56 (Avionics Sensor System-Recon)	very high unscheduled maintenance; (instructor does not want simulators)
3AZR30372-4	Keesler	AN/FPS-26A (Radar)	high unit cost; high unscheduled maintenance; instructor wants
3ABR30331	Keesler	AN/FPN-47 (Air Traffic Control Radar)	very high unscheduled maintenance; instructor wants
	Keesler	AN/TPX-42 (Air Traffic Control Radar)	poor trainer; instructor wants
3ABR30534-7	Keesler	AN/TSQ-91 (Electronic System Computer)	very high unit cost and unscheduled maintenance; (instructor does not want simulators)
3ABR36233	Sheppard	Titan II Missile Communication System	fairly high unit cost; instructor wants
	Sheppard	Minuteman Missile Communication System	fairly high unit cost; instructor wants
3ABR31632G-1	Chanute	Computer T/S and Digital Data Computer Set	high unit cost; poor trainer; instructor probably will accept
3AZR31670G-1	Chanute	Missile Launch Control Trainer	extremely high unit cost; (instructor does not want simulators)
3ABR42330	Chanute	CT-43 AC Power System	poor trainer
4TH Priority			
3ABR32232B	Lowry	AAD-7 Forward Looking Infra-Red Radar	high unscheduled maintenance; poor trainer; instructor probably will accept
3ABR32630B	Lowry	12A6830 Test Set	poor trainer; instructor may accept
	Lowry	12A16802 Receiver/Transmitter Modular Test Set	poor trainer; instructor may accept
	Lowry	12A16803 Computer Test Set	poor trainer; instructor may accept
3ABR30534	Keesler	AN/GSA-51 Computer System	very high unit cost; (instructor does not want simulators)
3ALR32850A-1	Keesler	ARC-96 TX Test Set & ARC-96 Receiver	instructor will accept
3ABR31632G-1	Chanute	AN/GSM-260 Guided Missile Test Station	very high unit cost; (instructor probably does not want simulators)

Table X. Classification of Trainers Which Are High Priority Candidates for Simulation

Type of Equipment	Simulation Priority 1st	2nd	3rd	4th	Sum
Test Set	2	4	4	4	14
Radar	1	2	4	1	8
Bomb/Navigation	-	1	-	-	1
Missile Control	-	-	1	-	1
Communications	-	-	3	1	4
Flight Simulators	-	1	-	-	1
Computer	-	-	2	1	3
Electro-optical	-	-	3	-	3
Electrical	-	-	1	-	1
Sum	3	8	18	7	36

The cost of training equipment may vary depending on whether it is an early or late production run. This information cannot be obtained from equipment custodians nor can information about R&D costs versus fabrication costs.

Based on the foregoing findings the authors judge that by using considerable caution, unit cost data obtained from a Technical Training Center can be used to determine the approximate cost and the relative cost of training equipment.

2. Hours of Unscheduled Maintenance. Column d of Table VIII shows the number of hours of unscheduled maintenance provided for items of training equipment over a 12-month period. This information can be obtained from printouts provided by a TTC's Consolidated Maintenance Squadron. We obtained data only for unscheduled maintenance because this type of maintenance is most disruptive to scheduled training.

According to present procedures for calculating equipment availability, training equipment can be available 8,760 hours per year (365 days x 24 hours). When a printout reveals that equipment was down for unscheduled maintenance for 8,000 hours that means it was unavailable for training purposes for 333 days. Large numbers of unscheduled maintenance hours are indicative of a lack of spare parts. As with unit cost data, the authors suspect that unscheduled maintenance data is somewhat inflated (this is based on a study of printouts of work orders and discussions with maintenance personnel), but the data is useful for determining the relative reliability of equipment.

3. Age of Trainer. The figure shown in column e of Table VIII represents the approximate age of a trainer assuming that the trainer was purchased by the school. Otherwise, the figure represents how long the trainer has been located at the school.

The age of a trainer is sometimes difficult to determine. It may be recorded on the Custodial Receipt Listing or on letters recording when the equipment first was received at the school. Other times, age of equipment must be supplied by an instructor--"That equipment must be about 17 years old because it arrived a couple of years before I started working here 15 years ago."

The equipment age figure was obtained because of the possible relationship between amount of unscheduled maintenance and equipment age. Inspection of Table VIII revealed no apparent relationship and the age figure was not incorporated into the formula for calculating simulation potential.

4. Instructor Judgements of Equipment Effectiveness. Question 1 of Questionnaire B, Part II required instructors to make specific judgements about specific training devices. Answers to the six parts of this question collectively provide an indication of instructor satisfaction with a particular piece of training equipment. The pattern of responses to this question suggested that the instructors did make discriminating responses--they did judge equipment to be effective but not reliable, easy to maintain but difficult to use to teach troubleshooting, and so on. The authors are of the opinion that the answers provided to the six parts of Question 1 provided more valid data than similar questions in Part I of Questionnaire B, or in Questionnaire A. Possibly this was because Question 1 called for specific judgements related to specific equipments.

5. Instructor Opinions About Simulators. Question 4, Questionnaire B, Part II was the only question which directly asked the respondent to express an opinion regarding the use of simulators. The pattern of responses provided to this question suggested that the respondents did provide discriminating replies to this question.

The relation between instructor opinions about simulators and their knowledge about simulators has already been discussed briefly (p. 22). In this survey we had an opportunity to talk with many instructors and could associate each respondent with a particular course and training device. Therefore, we were able to determine that of the 36 top candidates for simulation listed on Table IX, 19 of these were identified by Lowry AFB instructors known to be involved with or knowledgeable about simulation efforts related to the 12A6883 test bench. An additional nine of the 36 top simulation candidates were identified by instructors at Keesler AFB, most of whom were involved with or knowledgeable about an on-going simulation effort at that base. Finally, of the six high priority simulation candidates identified by Chanute AFB instructors, three of these pertained to flight simulators of the type for which simulator specifications were being developed.

Of the 36 simulation candidates listed in Table IX, only two were identified by Sheppard instructors. This may have been due to the types of courses (civil engineering, engine repair, helicopter maintenance, etc.) conducted at that base.

Weighting of Factors Which Comprise Simulation Potential Formula. The simulation potential ranking developed for each trainer listed in Table VIII was based primarily on four factors: the unit cost of the equipment; the cost of unscheduled maintenance; the judged effectiveness of the trainer; and the willingness of instructors to recommend the use of a simulator along with or in place of the actual equipment. With reference to Appendix H, it can be seen that the range of weights assigned to each of these four factors varied as follows: 0 to 35 for unit cost of trainer; 0 to 35 for unscheduled maintenance; 6 to 24 for effectiveness of trainer; and 1 to 23 for willingness to use simulators instead of or along with AETs. As a result of these weightings, cost considerations had a somewhat greater influence on the calculated simulation potential rankings.

Any formula for calculating the simulation potential of AETs will generate different results depending on the weights given to the factors incorporated into the formula. By varying assigned weights one can emphasize overall trainer costs or effectiveness, or any one or more of the factor elements used to determine cost or effectiveness. Before using such a formula therefore, one should examine the standard weights assigned to each factor and determine if they need to be adjusted to reflect local conditions and restraints. For example, at one TTC the overriding goal might be to reduce trainer costs. If so, cost factors in the simulation potential formula might be given double or triple weight. At another TTC the goal might be to obtain more effective trainers. Therefore, factors related to effectiveness should receive greater weight than that assigned in the basic formula.

The foregoing points may be obvious. However, we wish to emphasize that, in our judgement, decision formulas relating to training devices need to be adjusted to current and/or local conditions and restraints before they are applied. For example, it would make little sense to simulate equipment which is about to become obsolete or to simulate equipment used in a course which will soon be discontinued.

Evaluation of Usefulness of Questionnaire B, Part II.

Part II of Questionnaire B provided the most useful information during this survey, at least with respect to identifying actual equipment trainers which might be simulated. The information provided in response to the four questions contained in Part II, along with information about unit costs and hours of unscheduled maintenance, made it possible to develop a system for ranking actual equipment trainers in terms of the probable advantages which would be obtained if they were simulated. It was noted, however, that instructors tend to recommend the use of simulators to the extent that they are familiar with simulators and how they can be effectively employed

to teach maintenance on the type of equipment covered by their course. It would seem useful to continue the administration of Part II of Questionnaire B on a bi-yearly basis. Between administrations it would seem appropriate for the Air Training Command, in cooperation with AFHRL, to distribute to the Technical Training Centers the latest information on the effectiveness of various types of simulators which can be employed to teach equipment maintenance.

Use of Survey Procedures for Identifying the Need for Simulators

There are at least two general approaches which can be used to assess the need for simulators. One approach is to survey instructors and others familiar with maintenance courses. These persons can describe their likes and dislikes with respect to presently used training devices, and can provide opinions about the potential usefulness of other types of training devices. The validity of those opinions, however, may be suspect because instructors often are not aware of the various types of training devices and simulators which might be employed in their courses. In our judgement information and opinions provided by instructors can be used to identify problem areas and to identify the resistance which may be met to the proposed use of simulators in place of AETs. However, since instructors seldom are experts in the design and evaluation of training devices, they should not be expected to be able to provide a detailed analysis of the advantages and disadvantages of using simulators or other types of innovative training devices in their classrooms.

A second approach for assessing the potential for using simulators and/or other types of trainers is to have a simulation/training device expert examine a course in detail. This can include the in-depth questioning of course instructors. Based on the information developed the simulation expert can recommend various types of trainers for the course. This second approach is more time-consuming and expensive than the first approach (instructor survey), especially if applied to a large number of courses. The findings, however, are apt to be more valid.

It seems likely that the potential for using simulators can best be assessed by using a combination of the foregoing two approaches. The instructor survey approach can rapidly identify: (a) courses where training equipment is a problem; (b) courses which use costly equipment which is unreliable; and (c) courses where the use of simulators is acceptable to instructors. Once the potential areas for using simulators have been circumscribed by the survey approach, it is appropriate to analyze each area (course) in detail to determine if simulators can provide a solution to the training problem.

THE USE OF SIMULATORS FOR MAINTENANCE TRAINING: SOME SELECTION FACTORS

During the conduct of this study instructors provided innumerable comments relating to the comparative cost-effectiveness of simulators and actual equipment trainers (AET). As expected, most instructors were not completely convinced of the benefits to be gained by using simulators. Those known to have been heavily exposed to simulators tended to favor their use. Few instructors, however, had had the opportunity to employ simulators in their classroom. Thus, the questionnaires completed in this study contained many comments which in one manner or another suggested that simulators might be cost-effective under certain conditions but that more evidence was needed.

In a companion to this report (5), the authors reviewed published reports relating to the cost-effectiveness of maintenance training simulators. Most reports supported the contention that maintenance simulators can be effective, especially for teaching operator and troubleshooting skills. The literature also contained many estimates of the cost savings which potentially can be achieved through the adoption of simulators.

The pages which follow contain a review, in light of the aforementioned instructor comments and literature review, of some of the factors which should be considered when choosing between actual equipment trainers and maintenance simulators. Of course these are not the only alternatives. Other media--mock-ups, audio-visual programs, video tapes, obsolete equipment, etc.--might be more cost-effective under certain conditions.

When discussing the pros and cons of simulators versus AETs a wide variety of factors can be considered. Some of them are listed in Table XI. All factors have been subsumed under four headings--cost, availability, effectiveness and training environment. Whether or not simulators are costly, available when needed, and effective, depends in part on the setting in which they are used. Thus, at the end of this section we will discuss the use of simulators and AETs in relation to resident versus unit and/or Field Detachment training.

As part of the ISD (Instructional System Development) process decisions must be made regarding the type of media to use to support the teaching of various types of tasks. The general procedures for accomplishing this are described in AFR 50-2 and AFP 50-58. More definite ISD procedures for selecting training media are contained

in the June 1977 Mission Handbook of the 3306th Test and Evaluation Squadron. Even these procedures, however, do not consider all the factors which affect a decision to use simulators as opposed to actual equipment trainers. It is hoped that the discussion which follows will help lay the foundation for a more detailed decision matrix for making recommendations about the use of AETs or simulators for maintenance training.

Trainer Acquisition Costs

Number and Types of Tasks to be Supported by Trainer (Factor A1)[1]

The unit cost (excluding development costs) of most maintenance simulators is considerably less than the actual equipment they represent. How much less seems to depend upon: the number of tasks to be supported by the simulator; the complexity of the hardware required to simulate the equipment features relevant to the tasks to be taught; and the degree of physical fidelity built into the simulator.

In general, the more tasks you wish to teach using a particular simulator, the higher will be the cost of the simulator. A simulator should simulate only those portions of equipment related to the tasks to be taught through use of the simulator. Moreover, duplicate portions of equipment need not be simulated unless needed to teach certain check-out or maintenance activities. In the process of identifying simulator requirements one should identify those tasks which can be learned using low cost media, and those which can be best learned, or easily learned on the equipment itself. The remaining subset of tasks are those which the simulator should be designed to support. By reducing this subset to a minimum, the initial cost of the simulator can be reduced.

A simulator should have a fairly high degree of functional fidelity, but often this can be achieved without duplicating the physical fidelity of the equipment. Other things equal, the higher the physical fidelity requirements, the higher will be the unit cost of the simulator.

Weapon systems often employ highly sophisticated circuitry to accomplish certain goals. Sometimes the effects of this circuitry can be simulated by much simpler and less expensive means. For purposes of

[1] The reference to "factors" made in this and subsequent headings refers to the factors listed in Table XI.

Table XI. Factors Which Affect the Selection of Simulators as Opposed to Actual Equipment Trainers

A. Acquisition Costs

1. Number and Types of Tasks to be Supported by Trainer
2. Proportion of Displays and Operations That Must be Simulated
3. Need for Additional Front-End Task Analysis and Simulator System Design
4. Availability of Data for Determining Simulator Requirements
5. Feasibility of AET Modification
6. Number of Trainers Required
   a. Student Flow
   b. Number of Courses to be Supported by Trainer
7. Cost of AET

B. Life-Cycle Costs

1. Spare Parts
2. Configuration Management
3. Trainer Maintenance
4. Power and Environmental Control Requirements

C. Trainer Availability

1. Reliability
2. Ease of Maintenance
3. Ruggedness
4. Adequacy of Logistical Support
5. Probability of Trainer Recall for Operational Use

D. Trainer Effectiveness

1. Trainer Versatility
2. Need for Special Instructional and/or Performance Measurement Features
3. Stage of Learning Supported by Trainer
4. Maintenance Course Level

E. Training Environment

1. Field Training Detachment (FTD) Requirements
2. Impact of Task Oriented Training (TOT)
3. Availability of Other Media

teaching maintenance it often is sufficient to generate displays by mini-computers, a system of relays, or by other means. To the extent that simple hardware or software can be used to create the task characteristics required for training, the cost of simulators can be reduced.

Proportion of Displays and Operations That Must Be Simulated (Factor A2)

The cost of a simulator can be reduced considerably by not simulating some of the displays and operations of the equipment. For each maintenance task only certain displays and operational controls are relevant. The remainder are at least irrelevant and may even be distracting, especially to the novice technician. A careful identification and analysis of the tasks which will be taught using the simulator should identify a number of equipment features which need not be simulated or which can be simulated using low-cost techniques. The unit cost of simulators will be proportional to the number of equipment displays and controls features which must be simulated. Simulators designed to represent all features of their equipment counterpart may cost as much if not more than the actual equipment.

Need For Additional Front-End Task Analysis and Simulator System Design (Factor A3)

During the development of a new hardware system innumerable research, design, and development activities take place. The magnitude of these activities, along with the number of systems to be purchased, are reflected in the final unit price established for the hardware. A simulator is another piece of hardware and considerable front-end analysis must go into its development even though it is based on already designed equipment. The unit price, therefore, of a simulator may sometimes approach or exceed that for its operational counterpart because: much additional design and analysis must go into development of the simulator, and, only a small number of simulators are to be purchased.

Availability of Data for Determining Simulator Requirements (Factor A4)

For the past 25 years, sporadic attempts have been made to develop procedures whereby during the development cycle for new weapons systems detailed information about the system can be made available specifically for the purpose of designing training equipment, especially simulators

and mock-ups. Some persons have claimed that specifications for maintenance training devices cannot be prepared until the design of the parent weapons system has been established. Recent experience indicates that this is not so. During the Critical Design Review stage for a new system major design modifications seldom are made. Usually the equipment design and appearance becomes 80 to 90 percent fixed after the Initial Design Review stage. It should be possible, therefore, to begin the development of a simulator after its parent hardware has been modified on the basis of the initial design review. If changes are made to the weapons system thereafter, this usually will necessitate making only minor front panel changes on the maintenance training simulator.

Information required to develop simulator hardware and software can be obtained by working closely with the test and evaluation group working on early prototypes of the weapon system. Essentially, the foregoing describes the efforts of the ISD group which worked with the 3306th Test and Evaluation Squadron as they conducted tests and evaluation on the prototype F-16 aircraft. By working closely with the T&E squadron the group responsible for identifying training requirements was able to obtain the information they needed to develop the specifications for the F-16 Mobile Training Set trainers, most of which will be simulators. This case history demonstrates two important points: (1) data for the design of maintenance trainers is available fairly early in the design phase of a new hardware system; and (2) simulators can be designed on the basis of prototype hardware provided that you are willing to make last minute, minor reconfigurations to the simulator to reflect changes in the operational equipment design.

Feasibility of AET Modification (Factor A5)

When permissible to do so it may be less expensive to modify an AET than to purchase a simulator. In many instances this has been done, e.g., non-configuration managed actual equipment trainers have been modified to provide a fault insertion capability.

For existing weapons systems the possibility of modifying existing AETs or similar but obsolete equipment should be explored. If a school already owns the AET this often can be accomplished by the training services branch at little expense. This option should be considered after an analysis has shown that training equipment of some sort is required and that an AET might meet the requirements.

Number of Trainers Required (Factor A6)

The cost advantages of simulators become more apparent as the requirement for large numbers of trainers increases. Some maintenance courses need only one, or at least use only one, actual equipment trainer. Often this AET is used throughout much of the course. On the other hand, many maintenance courses employ two or more AETs. These courses seem to be the best candidates for simulators because one or more AETs can be replaced by simulators while still leaving one AET for use by the instructor. This approach should generate much less opposition to the use of simulators. Of course, the mix of AETs and simulators used in a course should be based on an analysis of training requirements and how they can best be met.

Student Flow. Each maintenance course POI contains, for each training device, a recommendation regarding the maximum number of students who should be trained simultaneously using that device. Generally, it is difficult to train large groups of students when they all have to work on the same piece of equipment. Some equipments, for example, are housed in vans which can hold no more than two or three students plus an instructor. Obviously, estimated student load is an important factor to consider when estimating the number of required trainers. Students can, of course, be taught in two or even three shifts, but time must be reserved for equipment maintenance. If you have more students to train you should have more training equipment. Thus, in high student-load courses more cost savings may be effected by using simulators.

Number of Courses to be Supported by Trainers. Most Technical Training Centers teach two or more similar maintenance courses, each course designed for a different skill-level student. Therefore, requirements for multiple copies of a training device depends both on student flow for a particular course and the number of courses which use the same trainers. It is preferable to schedule related courses so that they do not have concurrent requirements for identical trainers. This may not always be feasible. Therefore, it would seem advantageous to use simulators when they can be used in more than one course.

Cost of AET (Factor A7)

The procedures used during this study, and the formula for calculating simulation potential, both were based on the assumption that efforts to develop maintenance simulators should be directed to high cost AETs. This was in recognition of a fact that much of the current interest in simulation is due to the high unit cost of actual equipment trainers. As the cost of AETs continues to increase, the argument for using simulators should assume additional importance.

Current estimates in the literature of the relative unit cost of simulators vary from 10% to as much as 50% of the cost of actual equipment trainers (3, 12, 13). While such relative costs might continue to prevail, there also is the possibility that the cost of certain simulators may approach the cost of their actual equipment counterpart. If all portions of an AET must be simulated; if special instructional and/or measurement features must be incorporated into the simulator; and if extensive R&D is required to develop the simulator, then it is conceivable that a simulator could cost the same as or even more than its AET counterpart.

Life-Cycle Costs

The cost of maintaining a training device over a 15 to 20 year life cycle can be as much as or even considerably more than the initial cost of the trainer. A logistics system must be established for providing the trainer with spare parts. To prevent obsolescence the trainer may be configuration-managed. That is, it may periodically be updated to reflect the latest model of the operational equipment it represents. In addition, the trainer, as does all equipment, must undergo scheduled preventive maintenance and will most likely undergo unscheduled maintenance as well. For these actions the labor costs involved can be considerable.

Spare Parts (Factor B1)

Most estimates of the life-cycle costs of simulators conclude that the cost of spare parts will be considerably less than for a comparable AET. This is because simulators, in addition to being simpler and utilizing less costly components, also are less subject to breakdown. However, when simulators are employed an additional supply of spare parts must be maintained and special supply channels may have to be developed. If the simulator is configuration-managed then supplies will be provided by the Air Force Logistics Command. Otherwise, it may be up to the training institution to obtain spare parts wherever

it can. It may be necessary to resort to the cannibalization of obsolete equipment or even the fabrication of selected spare parts. Generally speaking, then, it is less costly to provide spare parts for a simulator than for an actual equipment trainer. However, if the manufacturer of the simulator is not willing to provide a source of supply on a long term basis then spare parts for a simulator ultimately may cost more than for an AET.

Configuration Management (Factor B2)

It is generally assumed that reconfiguring a simulator to reflect new equipment models will be less costly than reconfiguring a comparable actual equipment trainer. Again, this assumption is based on the observation that simulators usually are simpler, composed of cheaper components, and often may be more modularized than AETs. Also, many of the modifications affecting the AET may have no impact upon the simulator configuration. Most recently designed simulators use computer software to simulate expensive hardware circuitry. It usually is less expensive to modify this software than it is to modify electronic circuitry.

Trainer Maintenance (Factor B3)

Almost all life-cycle cost estimates developed in recent years for maintenance trainers have concluded that the cost of maintaining a simulator should be much less than the cost of maintaining a comparable AET. As compared with AETs, simulators tend to be more rugged, simpler, and more reliable. This should result in a longer mean time between failures and less average down time per failure for simulators. Periods of preventive maintenance must be scheduled for both AETs and simulators. But, because of their comparative simplicity, preventive maintenance on simulators can be performed in less time and less frequently.

Power and Environmental Control Requirements (Factor B4)

A standard complaint against AETs is that many of them consume large amounts of electricity and require special wiring in the training environment. Simulators also may require special wiring and consume considerable power. But, in most instances the power requirements for simulators are considerably less than for a comparable AET.

Actual Equipment Trainers may require a special operating environment, one that controls dust or humidity or dissipates heat. So also may simulators, but these requirements are less likely to prevail. Generally speaking, then, simulators are less costly to operate because they consume less power and often do not require a special operating environment.

Simulators as Replacements for or Additions to AETs

The discussion so far is most applicable to decisions regarding what type of maintenance trainer to purchase for new hardware systems. In recent years, however, simulators have received consideration as replacements for existing AETs or as additions to existing training equipment. It is difficult to justify replacing an existing AET with a simulator unless the AET had proven to be grossly ineffective or the cost of maintaining it had reached an unacceptable limit. Many maintenance courses, however, employ one AET and could use two or more additional ones. For such courses simulators can be especially cost-effective, and the cost considerations discussed above would apply. Even though the cost of the simulator would have to include the additional front-end analysis required to develop the simulator, one would not expect the simulator cost to exceed the unit cost of the AET, and life-cycle costs should be considerably less.

Trainer Availability

There are various reasons why an AET may not be available. It may not be developed on schedule and therefore will not be available for initial training on a new weapons system. After it becomes available for use it might become non-available because of maintenance or supply problems. Furthermore, it might be recalled to the field for operational use.

Reliability (Factor C1)

The cost of maintaining trainers is in part proportional to their reliability. If they malfunction it costs money to repair them. Obviously, while being repaired they are non-available for training purposes. For reasons already discussed, simulators tend to be more reliable than AETs and therefore should be more available for training.

Ease of Maintenance (Factor C2)

Ease of maintenance is related to the time required to perform preventive maintenance and the time required to repair unscheduled breakdowns. As compared with AETs, simulators generally require less periodic maintenance and can be repaired more rapidly once they malfunction. Again, this means that simulators should be more available for training than their AET counterparts.

Ruggedness (Factor C3)

A trainer is rugged to the extent that it can stand up to environmental conditions in the training environment, and can withstand heavy use and abuse by students. As compared with AETs, simulators are usually designed to withstand heavy student use. Instructors, therefore, are more apt to use simulators because there is less chance of breakdown. Moreover, many simulators are designed such that instructors can do things with them or to them which are not allowable on AETs, e.g., insert malfunctions. For these and other reasons the relative ruggedness of simulators makes them more available for training.

Adequacy of Logistical Support (Factor C4)

During this study it was found that certain AETs were down for unscheduled maintenance for up to 8000 hours during a 12-month period. We were told that this was an indication that spare parts were not available. As equipment ages it tends to malfunction more and thus requires more spare parts. It sometimes has been claimed that obtaining spare parts for AETs is a simpler process than obtaining them for simulators. In the past this may have been so since many simulators had been locally designed, and some had been developed by manufacturers who since have become defunct. Assuming, however, that simulators are purchased from reliable and substantial companies, it seems probable that, through contractual arrangements, an adequate supply of spare parts can be assured over the estimated life span of the trainer.

Probability of Trainer Recall for Operational Use (Factor C5)

Many AETs are configuration-managed. This is done in part so that,if required, the AET can be recalled to the field for operational use. When this occurs the AET obviously is non-available for training. This perhaps is one of the more compelling reasons for entertaining the possibility of using simulators instead of AETs. Currently, simulators are not subject to recall to field units even though the simulators may be configuration-managed.

Trainer Effectiveness

Trainer Versatility (Factor D1)

During the past three decades a number of research studies have shown that simulators can be used effectively to teach equipment operating and checkout procedures, and the conceptual aspects of troubleshooting. However, most simulators are designed to teach only a subset of maintenance tasks. It sometimes is assumed that, using AETs it is possible, or at least seems possible, to teach all maintenance tasks associated with the AETs. In practice this is not usually the case.

It often is not possible to subject AETs to heavy student use or to use them to support the teaching of certain maintenance tasks, especially troubleshooting tasks. For example, it usually is not permissible to insert certain types of malfunctions into actual equipment trainers for fear of damaging them. Moreover, because AETs are less able to withstand student abuse it is not advisable to use them to teach certain removal and replacement tasks. Finally, because of the time required to access test points, set up test equipment, etc., training tends to proceed slower on AETs than on simulators.

Simulators are designed to withstand student use, to simulate a selected set of critical malfunctions, and to allow trainees to by-pass some of the easy-to-learn but time-consuming activities related to maintenance. The versatility of simulators, therefore, relates to their capability to support the teaching of tasks which instructors sometimes are reluctant or unable to teach using AETs. Furthermore, often more students can be trained per unit time using simulators.

Need for Special Instructional and Performance Measurement Features (Factor D2)

AETs are designed to support an operational mission. They do not contain special: features for reporting student performance; stop-action features; instructional features; features for testing advanced trainees, and so on. These are but a few of the instructional and measurement features that can be incorporated into simulators. Of course some and perhaps all of these features can be incorporated into AETs which are not configuration managed. It is probably less expensive, however, to design these features into simulators than it is to retrofit AETs, especially if you first have to purchase the AET.

Stages of Learning Supported by Trainers (Factor D3)

The Methodology section of this report presented verbatim the Stages of Learning briefing given to the questionnaire respondents. That briefing subdivided the learning process into four stages (Table II) and associated each stage of learning with a particular group of training aids or devices which seem best suited to support learning during that stage (Table III). The briefing emphasized that: (a) simulators are most appropriately used to support the third stage of learning (skill acquisition in the training setting); (b) that AETs should be used to support the fourth stage of learning (skill mastery on the job); and (c) most maintenance training programs should employ a mix of AETs and simulators as well as less expensive media. The Stages of Learning briefing concluded by pointing out that decisions about the use of similators, AETs, and other types of media should be made with respect to the stage(s) of learning to be supported by the training media.

Maintenance Course Level (Factor D4)

Maintenance courses are conducted for 3-, 5- and 7-level personnel. The basic or 3-level maintenance course usually has an overall goal of training students to a point where they can perform rather skillfully in the training setting. Such courses teach maintenance activities at the first three stages of learning. Upon graduation students are assigned to a field unit where they receive additional task-specific training until they have acquired skill mastery on the job. This involves learning at the fourth stage.

Both resident and unit training rely heavily on the use of AETs, or operational equipment in the case of unit training. According to the learning scheme depicted in the stages of learning briefing, simulators should be very effective in a 3-level course but not necessarily so during unit training.

For some AFSCs, 5- and 7-level maintenance courses are conducted by Technical Training Centers. These courses are heavily oriented towards troubleshooting, advanced maintenance tasks and maintenance supervision. Most instructors feel that simulators are not suitable for such courses. This may be true to a degree. It seems more likely, however, that 5- and 7-level courses should use a mix of simulators and AETs whereas 3-level courses might use only simulators and non-operational mock-ups.

Training Environment

Field Training Detachments (FTD) Requirements (Factor E1)

Field Training Detachments are located at operational command bases but are manned by Air Training Command personnel. They conduct transition training on new weapons systems. As a new system becomes operational, FTDs teach experienced maintenance personnel how to maintain the new system. This is accomplished through the use of a Mobile Training Set (MTS) which may consist of a combination of AETs, part-task trainers, and simulators. FTDs also are provided with audio-visual programs for use when the MTS is not available. Transition training employs sophisticated high-fidelity trainers and operational equipment when available, and covers maintenance tasks at the third and fourth learning stages. Such training usually is not designed for novice technicians. Until recently this was not an important consideration. Now, because of increased emphasis on the appropriate location for training,the relation between simulators for transition training and for 3-level maintenance courses should be examined closely.

Impact of Task-Oriented Training (TOT)(Factor E2)

Throughout the Air Force there is increased emphasis on giving field units more responsibility for individual training, a responsibility that now resides mostly at the Technical Training Center level. This emphasis is being incorporated into a number of ATC programs which reduce resident 3-level training to 4 to 8 weeks. Following resident training the trainee is sent to the field where he receives either or both FTD and unit training. This training concentrates on teaching the specific tasks which 3-level mechanics of a particular unit must be able to perform.

The impact of the Task-Oriented Training concept has yet to be determined. Assuming its success, it seems probable that resident courses will be restructured so as to teach skills and knowledges at only the first and second stages of learning (see Table II). The training media requirements for such sources are those classified as classroom aids--charts, film and slides, animated viewgraphs, and so on. The research literature suggests that AETs are not required for such courses and simulators may not even be required. If they are, they probably would be used to teach only equipment start-up and operating procedures, and would not need a malfunction insertion capability.

According to the TOT concept, ATC still would be responsible for 3-level maintenance training. However, more of this training would be conducted by FTDs. Presumably, FTDs would need simulators or other types of training media to accomplish their training mission. Being co-located with an operational unit, they would have access to operational equipment. However, it might not be appropriate to use operational equipment for certain types of training, especially in view of published reports that AETs are less effective than simulators for teaching troubleshooting skills and certain other maintenance skills as well (5).

Availability of Other Media (Factor E3)

So far in this section we have concentrated on comparing AETs and simulators. However, there are other types of training devices and media which can be used to support maintenance training.

Questionnaire A (Appendix A) solicited opinions and information about the use of a variety of low-cost, low-fidelity devices for maintenance training. These devices would be appropriate for supporting learning at the first and second stages. Many instructors expressed a willingness to use more of these media provided that they were prepared for them.

During this study we talked with a number of persons who favored the more extensive use of audio-visual (A-V) programs and video tape. A-V programs currently are used by FTDs during transition training on new equipment. According to verbal reports, A-V programs, showing how equipment operates and how to perform certain maintenance tasks, are effective for use with experienced technicians. These persons can readily visualize maintenance actions and have less need for "hands-on" experience. The degree to which similar programs would be useful for training novice technicians is less clear. However, A-V programs and/or video tapes would seem useful during the first stage of learning. They can show what the equipment looks like, how it functions and what the job environment looks like.

Little has been said in this report about the use of mock-ups[1], either operational or non-operational. These devices can play an important role during the second stage of learning. Moreover, there are many maintenance tasks where non-operational equipment or mock-ups would be effective. Many removal and replace tasks, for example, can be taught with such training devices.

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[1] A mock-up is a 3-dimensional training aid built to scale and representing operational equipment. It may be a solid or cutaway model. A dynamic or operational mock-up allows an instructor to demonstrate manipulative principles, procedural steps or equipment movement in time and space (1).

Simulation Through the Use of Built-In Test Equipment (BITE) and Test Bench Computers

Newer weapons systems utilize BITE to check out electronic systems and their major components. Employing a computer program, the BITE can check out itself as well as the major electronic systems incorporated into the equipment of which the BITE is a part. Similarly, test benches employ computer programs to check out both themselves and the line replaceable units. To effectively use BITE and test benches the mechanic has to learn how to interpret a variety of front panel indicators. It may be possible to develop special computer programs so that both the BITE equipment and the test benches can be used to simulate their own malfunctions, malfunctions in LRUs or other system components.

Impact of Task Oriented Training (TOT) Programs on Simulator Requirements

As previously mentioned we suspect that the TOT program may reduce the need for simulators during institutional training and may increase the need for them during FTD and/or unit training. Furthermore, we suspect that the simulators now used by FTDs for transition training might not be appropriate for use with novice repairmen. As another possible impact, it may be that specialized FTDs will have to be created and all mechanics for a particular system sent to that specialized FTD before going on to unit training. The impact of the increased emphasis on the training of novice mechanics in the field bears close study over the next few years.

SUMMARY AND CONCLUSIONS

Ninety-eight Air Force instructors representing 100 different technical courses were administered two questionnaires in order to determine: (a) their opinions and current practices regarding the use of actual equipment trainers and low and medium cost/fidelity training devices and simulators; (b) the problems they were experiencing with training equipment; (c) the potential for using maintenance simulators in place of or along with actual equipment trainers; and (d) the usefulness of survey procedures for identifying resident training equipment simulation candidates. The study concentrated on identifying high-cost AETs which might be replaced by simulators. The 100 maintenance courses surveyed were conducted at four different Technical Training Centers located at Sheppard, Keesler, Lowry, and Chanute Air Force Bases.

Questionnaire A: Survey of Instructor/Training Personnel Opinions Regarding Use of Low and Medium Cost/Fidelity Training Devices and Simulators, was designed to identify the present and potential uses of various types of training devices and media for maintenance training. Salient findings based on Questionnaire A were:

1. Most instructors, regardless of the type of equipment covered in their course or the level at which the course was conducted, answered the questionnaire in a similar fashion.

2. In most courses actual equipment trainers were employed and instructors preferred it that way even though many complained about the reliability of those AETs.

3. Many instructors expressed a willingness to use less expensive training devices and media if they were provided with them and if they were convinced of their effectiveness.

Questionnaire B: Survey of Training Equipment Problem Areas and New Simulator Requirements for Maintenance Courses, had a two-fold purpose. The purpose of Part I of the questionnaire was to identify major problem areas associated with current training equipment. The questionnaire results revealed that few instructors registered complaints about the training equipment at their disposal. However, a substantial minority did report that they had problems with the reliability of their trainers.

The purpose of Part II of Questionnaire B was to identify high cost AETs which might be replaced in whole or in part by simulators. Eighty AETs were identified which had a unit cost of $100,000.00 or more. For each of these trainers the unit cost was determined as was the number of unscheduled hours of maintenance performed on the trainer during a recent 12-month period. A procedure was developed for rank-ordering the 80 AETs in terms of their potential for being replaced by simulators. The factors used to develop a "simulation potential" rank included: unit cost of trainer; number of unscheduled hours of maintenance per year; instructor judgments regarding AET reliability, effectiveness, ease of maintenance, ease of use by students and by instructors, capability of use when teaching troubleshooting; number of AETs employed in course; instructor judgments regarding need for additional AETs; and instructor judgments regarding the use of simulators to replace all AETs, to replace some AETs and to be used in addition to AETs. In the ranking formula cost and availability factors (unit costs and number of unscheduled hours of maintenance) and instructor judgments about the use of simulators received the most weight.

Using the ranking procedures 36 high-priority candidates for simulation were identified. Thirty-two of these represented AETs which were electronic in nature. Moreover, the bulk of these 36 trainers were listed by persons familiar with the effective use of simulators.

The validity of the data employed to calculate the simulation potential for training equipment was reviewed and it was concluded that (a) data related to unit cost of trainers and amount of unscheduled maintenance per year can be used to judge the relative but not absolute unit cost and reliability of trainers; (b) instructors can provide valid opinions about the effectiveness of training equipment with which they are familiar (Questionnaire B, Part II), but may express considerable reservations when asked to provide opinions about general classes of training devices (Questionnaire A and Questionnaire B, Part I); and (c) instructor opinions about the use of simulators seem positively related to their experience with simulators and the reliability of the AETs provided for their use.

After reviewing the data collected through the use of Questionnaires A and B it was concluded that: (a) the survey approach can be used to identify those equipments which are potential candidates for simulation, but the final determination of which equipments to simulate should be based on an in-depth examination by training and simulation experts;

(b) instructors are good sources of information on training problems but cannot be expected to make valid decisions about the use of training devices, such as simulators, with which they are unfamiliar; (c) survey instruments exemplified by Questionnaire A and Questionnaire B, Part I cannot be used effectively to identify AET simulation candidates; and (d) Questionnaire B, Part II typifies a survey instrument which can be used effectively to screen a large number of maintenance courses in order to identify expensive and/or problem-ridden AETs which might be replaced by simulators.

Based on the foregoing conclusions it was recommended that (a) the questions contained in Questionnaire B, Part I be merged into Questionnaire B, Part II, and that revised questionnaire be administered to selected instructors of all TTC maintenance courses on a bi-yearly basis; and (b) procedures be identified for conducting an in-depth examination of those equipments which, according to survey data, are candidates for simulation.

Some of the key factors which affect the use of simulators were discussed. These factors were reviewed under the headings of factors affecting: Acquisition Costs, Life-Cycle Costs, Trainer Availability, Trainer Effectiveness and Training Environment.

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APPENDICES

Appendix A

Questionnaire A

SURVEY OF INSTRUCTOR/TRAINING PERSONNEL OPINIONS REGARDING USE OF LOW AND MEDIUM COST/FIDELITY TRAINING DEVICES AND SIMULATORS

PART I[1]

The purpose of this survey is to obtain opinions about the probable use and effectiveness of various categories of training devices which in future years will be employed more extensively to train Air Force maintenance personnel.

This survey questionnaire covers four categories of trainers. These categories are:

Demonstrators
Nomenclature and Parts Location Trainers
Cue Discrimination Trainers
Part-Task Trainers

For each category of trainer a short briefing has been provided. This briefing material covers the purpose of the trainers, the research evidence relating to their effectiveness, and the ways in which trainers in the category will be used in the future. After reading the briefing material please answer the questions which follow. Then, move on to the next section of the questionnaire. When you have completed the questionnaire you may leave.

On the line below would you please record the name of a maintenance course with which you are very familiar. Then, answer all questions with respect to that course.

____
Name of Reference Maintenance Course

[1]Part I was completed for 56 courses.

SURVEY QUESTIONNAIRE

OPINIONS REGARDING THE USE OF LOW AND MEDIUM COST/FIDELITY TRAINING DEVICES & SIMULATORS

Section I -- Demonstrators

Briefing

The term "demonstrator" can refer to a variety of training devices which usually are employed in the classroom as instructional aids. Demonstrators are used to support the first stage of learning. They are used to introduce students to a weapon system, to the context of a maintenance job, to the operation of equipment and its sub-systems, and so on.

Demonstrators can be two dimensional or three dimensional; they can present a static display or show movement; they can be operational or be nonoperational. Examples of two-dimensional demonstrators include graphical materials such as wall charts and equipment diagrams, film strips, slides and transparencies, animated panels, and films and TV. Examples of three-dimensional demonstrators include mock-ups, models, equipment cut-aways and blown-up models.

Many research studies have shown that an inexpensive demonstrator often can be just as effective as an expensive one. For example, a number of studies have shown that:

1. Wall charts and transparencies often are as effective as animated panels and operational mock-ups.

2. Films and TV presentations can replace a demonstration using real equipment in the operational setting.

3. Mock-ups, if used only for classroom demonstration, can be replaced by wall charts and transparencies.

4. Cut-away charts can be substituted effectively for real equipment cut-aways.

5. Drawings can be just as effective as blown-up models.

What are the practical implications which follow from this research evidence? A general implication is that the use of expensive training devices for demonstrational purposes is usually a waste of money. More specifically, the research evidence implies that when you plan to use training aids or devices for demonstration only you should:

1. Use two dimensional aids instead of three dimensional devices.

2. Provide enough copies so that each student has one to practice on.

3. If you must use three dimensional devices, they should be non-operational. That is, use a mock-up where panels, displays, and so on are shown by using pictures rather than using real controls and displays which can be activated.

4. Use real equipment, actual equipment trainers, or sophisticated mock-ups and simulators only when they already are available because of other reasons.

That concludes the briefing. Please answer the following questions then go on to Section II.

Q-1 In your opinion, which of the following ways to demonstrate (familiarize students with) equipments are effective? Check all alternatives that apply.

a. 46 show the real equipment in operation.
b. 36 use a mixture of real equipment and 3-dimensional training aids.
c. 24 use films or TV.
d. 32 use 2-dimensional graphics such as slides, view graphs, wall charts, or equipment diagrams.
e. 4 other: please describe briefly.

Q-2 Do you use any mock-ups, cut-aways, or animated panels which in your opinion could be replaced by less expensive wall charts, transparencies, or other forms of 2-dimensional graphics?

a. 50 No
b. 6 Yes. If yes, please describe briefly.

Q-3 Do you agree that for classroom purposes charts and transparencies can replace non-operating mock-ups which are used only for demonstrations?

a. 42 Yes
b. 14 No. If no, comment briefly.

Q-4 Do you agree that cut-aways, wall charts and/or transparencies can serve as economical and effective substitutes for cut-aways of actual equipment or full scale mock-ups of equipment?

a. 39 Yes
b. 17 No. If no, comment briefly.

Q-5 Would you be willing to use less expensive training devices (wall charts, slides, transparencies, drawings of equipment) in place of operating mock-ups, equipment cutaways, and other more expensive training devices and simulators? Check all alternatives that apply.

a. 35 Yes, if there is evidence that they are effective.
b. 10 Yes, if they are provided to me.
c. 15 No, because I feel that real equipment or more realistic (expensive) training devices are more effective.
d. 10 Other. Describe briefly.

Q-6 Do you give students information about the context of various maintenance jobs?

a. – No
b. 5 Seldom
c. 25 Quite often
d. 26 Yes, usually

Section II -- Nomenclature and Parts Location Trainers

Briefing

This type of training device is used to teach students to "learn and locate objects or signals that are part of their work environment." Sometimes these trainers are called "Subject Matter Trainers."

The nomenclature and name of equipment parts, and the names of tools and test equipment, is taught during the first stage of learning. These subjects may be taught in greater detail during later learning stages. A variety of methods and devices are used to accomplish this. The traditional method involves laying out the items physically and having the students rehearse the names. A second method involves using pictures or graphics to show what the items look like. A third method involves having the student learn nomenclature while they learn other aspects of their job. For example, students can learn the names and locations of front panel control and displays while they learn operational checkout procedures.

The location of equipment parts, displays and controls can be taught by using real equipment, equipment mock-ups, various forms of operating and nonoperating cut-aways, and by the use of graphical materials, such as pictures or drawings.

For most maintenance jobs it is useful to learn a variety of factual information about the job context. This information need not be detailed and it probably doesn't help the student learn to do his job. However, it does provide the student with an understanding of how his future job contributes to the overall capability of a weapon system. This should increase the motivation and the job satisfaction of the student. Examples of context information which can be provided to the student include:

a. Information about typical job site layouts, to include the location of work benches, parts bins, units awaiting test, maintenance files, and so on.

b. Information about typical field operations, to include where equipment is used, what the site looks like, what the equipment looks like in operation, and so on.

c. Information about the duties, assignments and prerogatives of higher and lower echelon operators and maintenance personnel.

d. Information about the duties and job assignments of those persons who will work in the unit to which the student eventually will be assigned.

e. General information on wear and tear of equipment in special environments, such as hot climates, sandy sites, artic sites, humid climates, and so on.

The research evidence shows that the use of graphical materials to teach nomenclature is both effective and less costly than other methods. When this approach is used the names of parts usually are placed underneath the picture or drawing of the part. Often, however, the names are long and not easily read or pronounced. This problem can be lessened by providing an instructor to say the words or by furnishing an audio tape to pronounce the words. The use of an audio tape reduces instruction costs, especially when it is used to provide a front-end nomenclature learning module for each job. That is, when the students first begin to learn how to perform a new maintenance task, he studies audio-visual material which teaches him the name and the location of the parts which he will encounter during that task.

Most research evidence indicates that job context information can be taught effectively using a combination of graphics and verbal descriptions. The descriptions can be presented by auditory tape. The graphics can show the equipment, the space layout of the equipment, and so on. Flow charts can be used to show how a particular maintenance action or job position interacts with other maintenance actions or job positions, and with each operational and mission requirements. Much, if not all of this type of information, can be contained in self-instructional packages.

The Air Force is considering the increased use of pre-packaged graphic displays and audio tapes for teaching nomenclature, parts location and job context information. This training would not be given in a single session. Rather, it would be given during several sessions as appropriate throughout a course. It would begin with an overview of the equipment and its tactical setting. Panoramic views would be used to show the special relationship between equipment parts and subsystems. Later portions of the training would show smaller equipment parts. The purpose of this training would be to prepare students so that when they first worked around trainers or the real equipment, they already would know a great deal about the name and location of various parts of the equipment.

This concludes the briefing. Please answer the following questions then turn to Section III.

Q-1 When do you typically teach nomenclature of tools and equipment parts?

a. 39 Before students start using the tools or working with the parts
b. 17 When students first start working with the tools and parts.
c. 5 Other? Describe briefly.

Q-2 What training devices do you use to teach nomenclature? (Check all applicable answers.)

a. 37 Training aids.
b. 35 Equipment parts.
c. 38 Whole equipment.
d. 20 Mock-ups/simulators.
e. 9 Other

Q-3 When teaching nomenclature do you start with the big picture and work down to the details, or follow another sequence?

a. 42 Go from big picture to little picture.
b. 13 Go from details to the big picture.
c. 2 Follow no particular sequence.
d. 4 Other. Describe briefly.

Q-4 How do you show students where various parts of the equipment are located?

a. 41 Use actual equipment.
b. 24 Use Actual Equipment Trainer; equipment cut-away; mock-ups.
c. 30 Use wall charts, transparencies, slides.
d. 18 Use labeled diagrams.
e. 8 Other. Describe briefly.

Q-5 Would you use packaged material to teach nomenclature and/or parts location information if it were provided to you, or would you prefer to develop your own material?

a. 15 Yes, would use it all or most of the time.
b. 25 Yes, would use it some of the time.
c. 17 No, would prefer to develop my own material.

Comments:

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Q-6 To learn nomenclature, do you think that students need to touch and feel real parts and tools in addition to seeing graphics about them?

a. 30 Yes
b. 15 Sometimes
c. 11 No

Comments:

Q-7 Do you feel that nomenclature should be learned in the job context, as the names of parts and tools are used, rather than in several nomenclature packages?

a. 36 Yes
b. 16 Sometimes
c. 4 No

Comments:

Q-8 Do you feel that parts location should be learned in the job context, as the names of parts and tools are used, rather than in several nomenclature/parts location packages?

a. 38 Yes
b. 17 Sometimes
c. 1 No

Comments, if any:

Q-9 Do you feel that the location of equipment displays, controls, parts, etc. do not need to be specifically learned so long as there are maintenance manuals which contain this information in graphic form (location diagrams)?

a. 9 Yes
b. 10 Possibly, but not sure.
c. 37 No

Comments, if any:

Section III -- Cue Discrimination Trainers

Briefing

A repairman must learn to detect the presence or absence of a wide variety of cues, and must learn to discriminate between within and out-of-tolerance conditions. A wide variety of training devices have been used to support this learning. These devices teach students to recognize the presence of and the meaning of visual cues, different sounds, the smell of various fluids, how things should and should not feel, and so on. Mostly, these trainers are used to support learning during the early part of the second learning stage.

Maintenance personnel make heavy use of visual cues. For this reason they often depend on graphic displays contained in job performance aids and technical orders. Typically, students are taught to detect and to distinguish between visual cues in the context of learning a particular maintenance task. As a student learns the specific steps for a maintenance action he learns also the visual cues which guide each step. As he learns to perform an operational check of equipment, he learns to recognize within tolerance conditions. As he learns to perform preventive maintenance tasks, he learns to recognize cues which indicate that the equipment is operating properly. At the same time or later on, he is exposed to cues which indicate out-of-tolerance conditions.

Maintenance personnel often have to identify and discriminate between *non-visual stimuli. About 10 to 15 percent of the cues* used by maintenance men are non-visual, auditory cues being the most common of these. Most equipments make sounds when operating. Maintenance men must learn to recognize the sounds made by properly operating equipment and the sounds caused by various types of malfunctions and equipment wear.

Things that people smell while performing maintenance also are important. Repairmen of electronic and electrical equipment need to be able to recognize the smell of burning or overheated electrical insulation or components. Persons working around equipment containing a fluid may need to recognize the distinctive order of leaking hydraulic fluid or lubricating oil or fuel.

For certain equipments it may be important to learn tactile discriminations. For example, it may be important to recognize that a fastener is too loose or too tight. Tactile discriminations are difficult to learn outside of the job context. For this reason it seems best to learn about tactile cues in the context of learning a particular task.

Research has shown that by using pre-packaged simulation students can learn to recognize the presence of and to distinguish between visual cues. This learning can occur within or out of the job context, usually with equal effectiveness.

Technical orders and job performance aids are used to provide the repairman with information about the visual cues he should look for while performing a particular task. In addition, job performance aids can provide graphical material which shows what equipment should look like in its normal condition. The repairman can use this information to determine whether or not he has repaired the equipment properly. This same information can be contained in wall charts and other inexpensive visual display material. There seems to be no need to use three dimensional operating mock-ups or simulators for the sole purpose of showing students what various visual cues look like.

Considerable expenses may be involved in developing a simulator which provides the "vroom" of engine sounds. Rather than use high-priced simulators, audio tapes can teach the names of sounds, and how to distinguish between the sound of properly operating equipment and the sounds caused by various types of malfunctions.

Simulators can be developed which generate the odor of hydraulic fluid, various fuels, the smell of electrical fire, and so on. A much less expensive and equally effective procedure is to teach the names of olfactory cues through the use of containers of odors.

Please answer the following questions then go on to Section IV of the survey questionnaire.

Q-1 Describe briefly one or two training aids, devices and/or procedures you use to teach students to:

a. Detect or identify visual cues (meter readings, signs of equipment wear, signs of unsafe conditions, etc.)

b. Detect or identify various sounds found on the job (sound of a normal engine, sound of a loose engine valve, etc.)

c. Detect or identify various odors found on the job (smell of burnt insulation, leaking oil, etc.)

d. Recognize the feel of a properly torqued nut.

Q-2 Do you see any value in training students to recognize:

a. Odors found on the job?

1) 17 No
2) 14 Probably helpful
3) 25 Yes

b. Sounds found on the job?

1) 17 No
2) 15 Probably helpful
3) 25 Yes

Q-3 Would you use auditory tapes in your classroom to teach the names of job-related sounds, assuming that these tapes were provided to you?

a. 43 No
b. 12 Probably would
c. 7 Yes

Comments, if any:

Q-4 Would you use containers of odors in your classroom to teach the names of various job-related orders, assuming that these containers were provided to you?

a. 30 No
b. 12 Probably would
c. 13 Yes

Comments, if any:

Q-5 Describe briefly how the following types of identification of conditions (discrimination learning) is provided for in your classroom.

a. Visual discrimination learning, especially the recognition of differences between normal and out-of-tolerance conditions.

b. Auditory discrimination, especially the distinction between normal and abnormal equipment sounds.

c. Odor discrimination, especially the recognition of the difference between normal and abnormal equipment or job environment smells.

Q-6 Describe briefly any training devices, aids, or procedures used to show students:

a. The results of a maintenance action on a piece of equipment.

b. What various equipment parts look like before and after a maintenance action.

Q-7 Do you see any value in providing students with graphics which show:

a. The results which maintenance actions have on equipment?

1) 24 Yes
2) 17 Possibly, not certain
3) 15 No

If no, comment briefly.

b. Part location, and what parts look like before and after a maintenance action (show the difference between a normal part and a faulty part)?

1) 31 Yes
2) 12 Possibly, not certain
3) 13 No

If no, comment briefly.

Q-8 Maintenance personnel can learn the visual cues which distinguish between normal and abnormal conditions. Also, these cues can be shown graphically in Technical Orders. Can you see any reason why maintenance men should memorize the difference between good and bad equipment conditions when they can readily find this information in a well-constructed technical order? Comment briefly.

a. 25 No, I cannot
b. 22 Yes, I can
c. 9 Uncertain at this time.

If yes, please comment briefly.

Section IV -- Part-Task Trainers

Briefing

Most maintenance trainers used by the Air Force can be called part-task trainers. They are used to teach students how to perform particular tasks, or how to maintain particular portions of a weapon system. Most part-task trainers are used to support the second stage of learning, although the more sophisticated ones are used to support the third or skills consolidation stage of learning.

Some portions of a task are easy to perform, other portions are difficult. It makes sense to provide an appropriate amount of time to learn each task. When a training device requires the student to perform many different tasks in order to learn one of them there is no easy way to provide different amounts of practice for different tasks. For this reason the Air Force uses a wide variety of part-task trainers. In fact, with a few exceptions, most trainers used by the Air Force can be called part-task trainers. These trainers can be very simple, like soldering kits, or they can be quite complex like a flight engineer panel mock-up. They can represent an entire equipment sub-system, a major component of a sub-system, or only a small section of a component. They are developed and used whenever training personnel feel that students need special training and practice on a portion of a task. Examples of part-task trainers include Electric and Hydraulic System Trainers, Armament System Maintenance Trainers, Fuel System Trainers, Power Plant Trainers, and so on. Troubleshooting Logic Trainers are a special class of part-task trainers and are covered separately in Part II of this questionnaire.

Most part-task trainers are used to support the second stage of learning. They are used to teach students the relationship between controls and displays. They can be used to teach the use of test equipment. Early in the learning of a complex task they can be used to teach students to collect and interpret cues in terms of what action should be taken next. Often they are used to teach procedures.

The general purpose of a part-task trainer is to train students to respond without error. Their responses need not be quick, or smooth, or coordinated so long as they are errorless. During later learning stages they learn to respond skillfully. Put another way, the general purpose of a part-task trainer is to prepare students to practice on more sophisticated trainers and on real equipment. Keeping this purpose in mind, you can see that part-task trainers don't need to be very real looking. In fact, the

research evidence shows that low fidelity training aids and devices are just as effective if not more so than high-fidelity part-task trainers. This is especially true for trainers used to teach procedural sequences. Here the research clearly indicates that low-cost, low fidelity simulators can be just as effective as high cost devices and real equipment. In fact, most of these studies show that the effectiveness of a training device depended more on how it is used during training than on how expensive or real-looking it is.

It should be added, of course, that we are not suggesting that low fidelity trainers can be used by themselves, to produce highly skilled equipment operators or repairmen. Perhaps they can in some instances.

In general, however, there is overwhelming evidence that low-cost, low fidelity part-task trainers can be used effectively to prepare students to practice on higher-fidelity trainers. By taking this approach to the use of training devices, maintenance courses can become more effective and less expensive.

Will you now please answer the questions contained on the following page.

Q-1 List the names of two or three part-task trainers used in your course.

Q-2 With respect to the part-task trainers available for your use:

a. What do you like most about them?

b. What do you dislike most about them?

Q-3 Would you make more use of part-task trainers if more of them were made available to you?

a. 11 Yes
b. 20 Probably would
c. 11 No
d. 6 Not certain

Q-4 How extensively do you use part-task trainers in your course?

a. 23 in less than 10% of the course.
b. 2 in 10 to 20% of the course
c. 7 in 20 to 30% of the course
d. — in 30 to 40% of the course
e. 7 in 40 to 50% of the course
f. 1 in 50 to 60% of the course
g. 6 in over 60% of the course

You have now completed this questionnaire. Please hand it in to the survey administrator, then you may leave. Thank you very much for your assistance.

Questionnaire A

SURVEY OF INSTRUCTOR/TRAINING PERSONNEL OPINIONS
REGARDING USE OF LOW AND MEDIUM COST/FIDELITY
TRAINING DEVICES AND SIMULATORS

PART II[1]

The purpose of this survey is to obtain opinions about the probable use and effectiveness of various categories of training devices which in future years will be employed more extensively to train Air Force maintenance personnel.

This survey questionnaire covers three categories of trainers. These categories are:

Troubleshooting Logic Trainers
Job Segment Trainers and Simulators
Actual Equipment Trainers and Operational Equipment

For each category of trainer a short briefing has been provided. This briefing material covers the purpose of the trainers, the research evidence relating to their effectiveness, and the ways in which trainers in the category will be used in the future. After reading the briefing material please answer the questions which follow. Then move on to the next section of the questionnaire.

When you have completed the questionnaire you may leave.

On the line below would you please record the name of a maintenance course with which you are very familiar. Then, answer all questions with respect to that course.

____
Name of Referenced Maintenance Course

[1]Part II was completed for 44 courses.

Section V -- Troubleshooting Logic Trainers

Briefing

Maintenance men spend fifty percent or more of their time troubleshooting equipment. For this reason the Air Force and the other Services have developed a variety of training devices designed primarily to teach troubleshooting skills. Most of these trainers are designed to teach the logical, conceptual aspects of troubleshooting. They are used to teach students how to collect symptom information, how to interpret cues, how to interpret display readings, how to select test points and interpret test point readings, and how to use all this information to isloate a malfunction to a Line Replaceable Unit or to a replaceable component. Troubleshooting Logic Trainers are a type of part-task trainer and are used to support the third stage of learning.

The Air Force has a long history of supporting the develcoment of logical or conceptual troubleshooting trainers. Perhaps you are familiar with some of the ones developed in the 1950s and 1960s. There were the E-4 Fire Control System Trainer, the MAC-I and MAC-II Trainers, the GETS Trainers, the CAM or Checkout and Maintenance Trainer, and the DC Electricity Trainer. These trainers presented malfunction symptoms, allowed students to simulate the manipulation of controls and to observe changes in front panel displays, and allowed the instructor to insert malfunctions using an instructor console. In addition, most of them recorded student performance and provided some type of feedback to the student.

Troubleshooting Logic Trainers may be systems specific or general purpose. If they are designed to simulate a specific system or subsystem, and cannot be easily modified to represent another system, then they are systems specific. In contrast, a general purpose trainer can be rather easily modified to simulate a variety of systems or subsystems. However, they cannot provide a high fidelity simulation of equipment controls and displays.

In recent years many improvements have been made to general purpose simulators. Two examples which you may already know about are the EC-II and EC-3 produced by the Educational Computer Corporation, and the Automated Electronic Maintenance Trainer developed by Minn. Honeywell. Both of these trainers can be used to teach the purpose of controls, the interpretation of normal versus malfunction operation, the performance of system self-checks or system check-out procedures, and troubleshooting techniques. Both trainers, and especially the EC-II, have been used in a number of research studies and field tests, and the evidence is that they are a cost-effective device. These two trainers and similar ones produced by other manufacturers probably will be used more and more as their effectiveness becomes more widely known.

This completes the briefing. Will you now please answer the questions in Section V-A and V-B which deal respectively with systems specific and general purpose troubleshooting logic trainers.

Section V-A -- Troubleshooting Logic Trainers: Systems Specific

Q-1 Describe briefly any systems specific troubleshooting trainers used in your maintenance course.

Q-2 Would you prefer to teach troubleshooting techniques by:

a. 19 Using Actual Equipment Trainers (AET):
b. 6 Using systmes specific troubleshooting logic trainers
c. 16 Using a mixture of systems specific troubleshooting logic trainers and AET
d. 4 Using TOs and lectures
e. 5 Other. Please describe.

Q-3 When teaching troubleshooting techniques, do you teach also how to use Technical Orders?

a. 2 No
b. 6 Yes, sometimes
c. 35 Yes, all or most of the time

Comments, if any:

Q-4 In your judgment, are Technical Orders prepared in enough detail so that trainees do not have to learn much about troubleshooting?

a. 17 No
b. 14 Sometimes, but most TOs still need more detail
c. 9 Yes, most TOs detailed enough to eliminate need for extensive troubleshooting practice during training.
d. 6 Other. Please describe.

Q-5 In your opinion can systems specific Troubleshooting Logic Trainers be used instead of real equipment or Actual Equipment Trainers to teach troubleshooting skills?

a. 18 No, all training should be conducted on AETs or real equipment
b. 9 Yes, but most training still should be on real equipment or AETs.
c. 14 Yes, but final stages of learning should occur using real equipment.
d. 2 Yes, don't need to use AETs or real equipment during training.

Q-6 With respect to the systems specific Troubleshooting Logic Trainers <u>available for your use</u>:

a. What do you like most about them? Describe briefly.

b. What do you dislike most about them? Describe briefly.

Q-7 Would you make more use of systems specific Troubleshooting Logic Trainers *if they were made available to you?*

a. 11 Yes
b. 14 Probably would
c. 14 No
d. 4 Not certain

<u>Comments, if any</u>:

Section V-B -- Troubleshooting Logic Trainers: General Purpose Trainers

Q-1 Are you familiar with any general purpose Troubleshooting Logic Trainers?

a. 19 No
b. 7 Not certain
c. 17 Yes

If yes, list their names, if known to you.

Q-2 Do you employ any general purpose Troubleshooting Logic Trainers in your maintenance course?

a. 16 Yes
b. 27 No
c. — Not sure

If yes, describe briefly.

Q-3 From what you know about systems specific and general purpose Trouble-shooting Logic trainers, which would you prefer to use?

a. 17 Systems specific trainers
b. 6 General Purpose trainers
c. 2 Can't see that it makes any difference
d. 4 Neither one
e. 10 Don't have enough information to make a choice
f. 6 Other. Please describe.

Q-4 With respect to the general purpose trainers available for your use:

a. What do you like most about them? Describe briefly.

b. What do you dislike most about them? Describe briefly.

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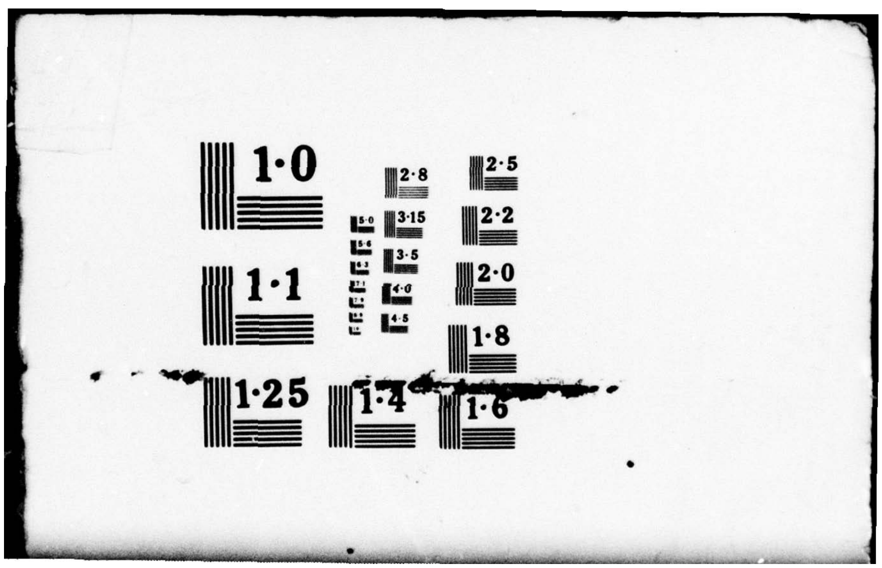
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Q-5 Electronic equipment maintenance men may spend 50 percent or more of their time troubleshooting equipment. During training, however, only 10 percent or less of a course is used to teach troubleshooting skills. If you were provided with all the specific or general purpose Troubleshooting Logic Trainers you wanted, plus one or two Actual Equipment Trainers, how much course time would you allocate to teaching troubleshooting logic and skills?

a. 3 Less than 10%
b. 8 10 to 20%
c. 14 20 to 30%
d. 6 30 to 40%
e. 5 40 to 50%
f. 5 over 50 percent

Section VI -- Job Segment Trainers and Simulators

Briefing

In some instances it is not possible to practice on real equipment, nor can operational equipment be made available for training. In these situations high-fidelity simulators have to be used during training. Most training devices of this type simulate an entire weapons system or a major segment of it, or simulate an entire job. The work environment and working conditions may be replicas of the real operational situation. Examples of these types of trainers are a flight trainer, an operational mock-up of a ship's bridge, and the control room of a missile complex. Trainers of this type are used to provide practice on large segments of a job. They are used to support the third stage of learning, especially the later portion of that stage. They are used also to support the fourth stage of learning when real equipment cannot be used for that purpose. This category of trainer is used to support the fourth stage of learning. The student has progressed to a level where his activities are fairly automatic. He now needs practice to make them more so. The trainers must bear a strong physical resemblance to the real equipment to assure maximum transfer of training to the real equipment. Most training devices of this type simulate an entire weapon system.

There aren't many training situations where a complete job or a major segment of it is represented by a simulator. Missile maintenance personnel may be trained to troubleshooting using a full-scale mock-up of a control room. The test sets used to test and troubleshoot aircraft line replaceable units have been constructed in the form of partially operating mock-ups. These devices, when mated with a malfunction generator and student console, provide a simulation of a major portion of a job. The Automatic Electronic Maintenance Trainer produced by Honeywell is evoluting towards a job segment trainer.

Now, please answer the questions that follow.

Q-1 Do you use job segment trainers or simulators in your maintenance course?

a. 27 No
b. 2 Not sure
c. 6 Yes, for a few hours of training only
d. 8 Yes, used extensively
e. 1 Other. Please explain

If yes, please briefly describe the type of trainer or simulator used.

Q-2 With reference to the use of job segment trainers and simulators:

a. What do you like most about such trainers and simulators?

b. What do you dislike the most about such trainers and simulators?

c. Are there other training devices you would like to use in place of job segment trainers and/or simulators?

1) 21 No
2) 7 Yes. Explain briefly.

Q-3 Are there any tasks, skills or knowledges now taught through the use of job segment trainers or simulators which, in your judgment, could be better taught by using other types of training devices? If your answer is "yes," list some of those tasks, skills or knowledges, and then list the training device which you would like to use to teach it.

Illustration:

Interpretation of front panel displays -- troubleshooting trainer
Location of controls and parts -- actual equipment trainer

Section VII -- Actual Equipment Trainers and Operational Equipment

Briefing

In most maintenance courses actual equipment is used for training whenever possible. In most instances this equipment is no different from operational equipment. Much of this equipment is relatively small and inexpensive and it probably would not be cost-effective to develop training simulators to replace them. However, low cost graphical material can be used effectively to teach nomenclature, parts location, and equipment set-up and operation of such equipment.

Many types of actual equipment trainers are large, costly to purchase and maintain, and may require special classroom conditions such as air conditioning, special power, reinforced flooring, and so on. Many must be placed on test stands. If real equipment is set up to be operational in a training laboratory, it also must be placed in a special environment, provided with special power, and so on. In addition, it usually is noisy and possibly dangerous to work around.

As you already know, real equipment and actual equipment trainers are not designed for training. They may not be very rugged. Usually it is not easy to insert a variety of malfunctions into them, and it may be dangerous to do so. Often it is difficult for more than one student to work on the equipment. Often it takes a long time to run through a single troubleshooting problem. Actual equipment trainers have no provision for providing feedback to the student or for keeping track of his progress. Finally, actual equipment trainers often are inoperable because of malfunctions and lack of spare parts.

On the positive side, they do look like real equipment. You would hope, therefore, that whatever is learned on an actual equipment trainer will transfer to the real equipment. Of course, the trainer may be, and often is, obsolete.

For smaller pieces of equipment it undoubtedly is easier and perhaps cheaper to purchase additional equipment for training than it is to design and purchase a mock-up or simulator of the equipment. However, as the real equipment gets larger and more expensive, it becomes more cost-effective to replace them with a training device. During this session we have covered many of the reasons why mock-ups and simulators, and low cost training devices should be used instead of real equipment.

In closing this briefing, let me repeat what we said earlier about real equipment. We said that we are not against the use of real equipment for training purposes, rather, we are opposed to the overuse of expensive equipment when low cost training devices and medium cost simulators can be effectively used instead.

This concludes the briefing. Would you now answer the following questions.

Q-1 Do you use any large or very expensive Actual Equipment Trainers in your Course?

a. 7 No
b. 5 Yes, for a few hours of training only
c. 32 Yes, used extensively
d. — Not sure
e. — Other, please explain

Q-2 With reference to the use of Actual Equipment Trainers:

a. What do you like most about such trainers?

b. What do you dislike the most about such trainers?

c. Are there other training devices you would like to use in place of actual equipment trainers?

1) 26 No
2) 17 Yes. Please explain

Q-3 About how many hours per month do you use the actual equipment trainers assigned to your course?

a. 1 less than 20 hours.
b. 6 between 20 and 40 hours.
c. 8 between 40 and 80 hours.
d. 11 between 80 and 120 hours.
e. 6 between 120 and 160 hours.
f. 9 over 160 hours.

Q-4 Throughout this questionnaire we have suggested that a training program should use a variety of both low-cost and higher cost training devices and simulators to replace the use of operational equipment and Actual Equipment Trainer. However, we said also that students should have an opportunity, either during school, or on the job, to practice on operational equipment or at least on Actual Equipment Trainers and Job Segment Trainers and Simulators. If this general plan is followed it will mean cutting back on some, but not all, use of real equipment during training, and increasing the use of both medium-priced and low-cost training devices. To what extent do you agree with this general approach?

a. 10 I don't agree with it at all
b. 8 I agree somewhat but am not fully convinced that it is a good idea.
c. 11 I think I agree and am willing to see the approach tried in more courses.
d. 10 I agree quite fully but see some problems that need to be handled.
e. 5 I am in complete agreement with the approach.

Your comments, if any, will be appreciated.

You have now completed this questionnaire. Thank you for your participation. Please feel free to record any last comments about this survey or the briefing or questionnaire material.

9-1-77

Appendix B

SURVEY OF TRAINING EQUIPMENT PROBLEM AREAS AND NEW SIMULATOR REQUIREMENTS FOR MAINTENANCE COURSES

Instructions. The purpose of this survey is to identify problem areas which relate to the use of training equipment for maintenance training. A second purpose is to identify new training requirements for simulators. On the line below would you please record the name of a maintenance course with which you are very familiar. Then, answer all survey questions with reference to that course.

____

Name of referenced course

Questionnaire B

Part I

TRAINING EQUIPMENT: MAJOR PROBLEM AREAS

1. In your opinion, has sufficient numbers of training equipment been provided for this course?

   a. 15 No b. 82 Yes c. 3 Uncertain

   If "No", please provide a brief justification for your answer.

2. In your opinion, is the training equipment provided for this course adequate? That is, can it be used effectively for training?

   If "No", please provide a brief explanation for your answer.

   Yes = 81 No = 19

3. Do you find that the training equipment provided for this course is often non-available? That is, do you often find that you cannot use the equipment when you want to?

   a. 74 No b. 23 Yes c. 3 Uncertain

   If "Yes" describe briefly the reason(s) why the equipment is not available.

4. Has your use of course training equipment been constrained because it costs too much to use the equipment?

   a. 92 No. b. 7 Yes c. 1 Uncertain

   If "Yes", briefly describe one or two instances where you have not been able to use training equipment because of cost considerations.

5. Sometimes training equipment can be made more effective or easier to use by making modifications to it. Have you been constrained from making or requesting modifications to any of the training equipment provided for this course?

   a. 15 Yes b. 80 No c. 5 Uncertain

   If "Yes", please provide one or two examples.

TRAINING EQUIPMENT: MAJOR PROBLEM AREAS (Cont.)

6. In your judgment, is the training equipment provided for this course reliable or does it break down a lot?

   a. 43 Yes, it is reliable

   b. 18 No, it breaks down a lot

   c. 37 About average in reliability

   d. 2 Uncertain

7. In your opinion, are there critical training areas of this course which are not properly supported by training equipment?

   a. 16 Yes b. 79 No c. 5 Uncertain

   If "Yes", please provide a brief justification for your answer.

PART II

AET AND SIMULATOR REQUIREMENTS

Instructions

Assume that you are in the process of completely revising your course and now are looking at your training equipment requirements. Assume also that you have been asked to pay special attention to your need for large, expensive actual equipment trainers, those that might cost $100,000.00 or more to purchase today. Based on these assumptions please proceed as follows:

1. Go through your POI page by page and identify all of the actual equipment trainers used which probably cost at least $100,000.00. (If the equipment is sizeable or complex it probably costs at least one-half million.) List the name of each AET (actual equipment trainer) at the top of one of the columns provided on the attached "Actual Equipment Trainer Data Sheet."

2. For each listed AET answer the questions contained in the left column by checking one of the four Yes-No sub-columns under the name of the AET. Rough definitions for each of the four sub-columns are as follows:

   .. "Yes-1" - Definitely Yes

   .. "Yes-2" - Probably/Usually Yes

   .. "No-3" - Probably/Usually No

   .. "No-4" - Definitely Not.

3. If you need more data sheets, they can be provided by the person who is administering this questionnaire.

4. Your course may not use expensive actual equipment trainers. If you think none of the trainers used in your course cost $100,000.00 or more, check below. Please review your POI carefully before making this check.

   .. _____ In my opinion my course does not use trainers which cost $100,000.00 or more.

ACTUAL EQUIPMENT TRAINER DATA SHEET

Name of AET							
Questions	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
	Yes No	Yes No	Yes No	Yes No	Yes No	Yes No	Yes No
	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Q-1: Is this AET:							
a. Effective?							
b. Reliable?							
c. Easy to Maintain?							
d. Easy for students to use?							
e. Easy for instructors to use?							
f. Use to teach troubleshooting?							
Q-2: How many AETs do you have now?							
Q-3: Do you need more AETs?							
Q-4: Could you use simulators:							
a. <u>In addition</u> to AETs?							
b. To replace <u>some</u> AETs?							
c. To replace <u>all</u> AETs?							

Course Number: ____________

Appendix C

DEVELOPMENT AND CONDUCT OF A SURVEY FOR DETERMINATION OF THE REQUIREMENTS FOR AND POTENTIAL USES OF SIMULATION IN AIR FORCE TECHNICAL TRAINING

Contract F33615-77-C-0051

Project Briefing

Good morning, gentlemen. My name is ________________ and I am an educational psychologist employed by Kinton, Incorporated of Alexandria, Virginia. I am here today to tell you about a project Kinton is conducting for the Air Force. This project is concerned with determining the requirements for and the potential uses of simulation in Air Force Technical Training, and is concerned specifically with the devices used to train maintenance personnel. The project is sponsored by the Technical Training Division of the Air Force Human Resources Laboratory located at Lowry AFB, Denver, Colorado.

The problem which led to the present study is that expensive training devices often are employed when less expensive devices could serve as effective substitutes.

We all are well aware that training is a very expensive undertaking. In addition to the salaries of training personnel, students and support personnel, the cost of plant facilities, and a host of other cost categories, there is the cost of purchasing and maintaining training devices, simulators and real equipment used for training. In some instances, pilot training being the best example, there seems to be no effective alternative to the use of expensive simulators and real equipment. However, with respect to maintenance training, there are alternatives. Since 1950 considerable research evidence has been

accumulated which shows that real equipment, actual equipment trainers, and expensive simulators and training devices often are used for training when lower cost and fidelity devices would be equally effective.

The goal of this project is to develop a simulation technology which can be used by the Air Force Training Command and by System Program Offices to lesson problems associated with the high initial and recurring costs of many training devices. The products of the project will allow the ATC and SPOs to identify more readily those portions of training where low cost, low fidelity training devices can be employed effectively.

There are a number of reasons why the evidence in favor of low cost training devices is not applied more widely. Those responsible for the instructional systems development of a course often do not have the specific task analytic information needed to determine training device requirements. Moreover, the guidance provided to course developers implies that, when in doubt, you should select the most "real looking" training device you can afford. In practice this means actual equipment trainers whenever possible. Furthermore, training device requirements and specifications usually are developed by manufacturers of prime equipment who either are unaware of the research evidence that points to the effectiveness of less expensive training devices, or, they have reasons for promoting the use of trainers which look and function like the real equipment.

To accomplish this project training personnel at TTCs and at selected Air Force Bases will be surveyed to identify the current and potential use of various types of training devices and simulators. Information will be collected about their current and potential use in the classroom, for field training, and for OJT; their reliability and maintainability; their training

effectiveness; their advantages and disadvantages as training devices; and their initial and recurring costs. Concurrently, a second survey of training personnel will be conducted to determine their reaction to the use of various types of low cost, low fidelity training devices. Based on research evidence, we will propose to groups of instructors recommendations regarding the use of various types of low cost and fidelity devices, and then will ask them to tell us if such devices would be effective in their courses.

As part of this project we will, via a review of the research literature, compile evidence for the effectiveness of low cost training devices and simulators. Finally, the future need for various types of simulators and training devices will be reviewed with interested agencies such as Headquarters, ATC: Headquarters, TAC; Special Project Offices; and the Naval Training and Equipment Center.

The products produced by this project will be as follows: we will compile information on the usage and cost of selected training devices, simulators, actual equipment trainers, and operational equipment used primarily for training. We will compile information on the planned-for use of training devices in future programs such as those for the F-16. We will compile factual evidence relating to the use of low and medium cost and fidelity training devices and simulators. Fourthly, we will develop a simple scheme for classifying training devices. And, lastly, we will develop recommendations regarding the substitution of lower cost and fidelity training devices for those of higher cost and fidelity.

As a result of this project we will be able to develop improved guidance for selecting training devices, guidance which should lead to a reduction in the cost of purchasing and maintaining the Air Force's vast inventory of devices used for the training of maintenance personnel.

This concludes this briefing. Are there any questions?

QUESTIONNAIRE A

Answers to Open-Ended Response Questions

Part I, Section 3

Q-1 Describe briefly one or two training aids, devices and/or procedures you use to teach students to:

a. Detect or identify visual cues (meter readings, signs of equipment wear, signs of unsafe conditions, etc.).

25[1] .. use actual equipment
1 .. use modified AET with fault insertion capability
1 .. use signal generators
13 .. use meter reader trainer, meters, oscilloscopes, common test equipment
2 .. use gauges to check adjustments
5 .. use slides, pictures, diagrams, transparencies
4 .. not taught/covered
2 .. use equipment trainer
1 .. use special test equipment/test set
4 .. use mechanical faults (broken pins, parts, components)
1 .. use alignment/adjustment trainer
1 .. classroom discussion
2 .. use TOs
2 .. use programmed packages
1 .. use circuit boards

b. Detect or identify various sounds found on the job (sound of a normal engine, sound of a loose engine valve, etc.).

17 .. use actual equipment, sound of components (motors, relays, etc.)
2 .. special test equipment (vapor detector, ultrasonic detector, etc.)
16 .. area not covered/area NA
2 .. use equipment trainer
2 .. discussion
1 .. use TOs

c. Detect or identify various odors found on the job (smell of burnt insulation, leaking oil, etc.).

5 .. use equipment trainer
2 .. use actual equipment, components
1 .. description, discussion
13 .. not taught
1 .. special test equipment

[1]Number of respondents providing this or a similar answer

d. Recognize the feel of a properly torqued nut.

15 .. use torque wrench
5 .. use actual equipment, remove and replace on AET
2 .. use torque trainer
12 .. not taught/NA

Q-5 Describe briefly how the following types of identification of conditions (discrimination learning) is provided for in your classroom.

a. Visual discrimination learning, especially the recognition of differences between normal and out-of-tolerance conditions.

24 .. actual equipment trainers
15 .. test equipment/meters/measuring equipment
10 .. TOs
7 .. slides, pictures, diagrams, transparencies, training aids
1 .. programmed packages
1 .. equipment trainer
1 .. component inspection
1 .. discussion/demonstrations

b. Auditory discrimination, especially the distinction between normal and abnormal equipment sounds.

21 .. actual equipment/take advantage of equipment malfunctions
2 .. trainers
4 .. discussion
18 .. not taught/NA
1 .. TOs
1 .. programmed packages

c. Odor discrimination, especially the recognition of the difference between normal and abnormal equipment or job environment smells

8 .. actual equipment when it malfunctions (smell, etc.)
1 .. equipment trainer
3 .. discussion
24 .. not taught/NA
1 .. smell of chemicals

Q-6 Describe briefly any training devices, aids, or procedures used to show students:

a. The results of a maintenance action on a piece of equipment

29 .. actual equipment/operational check
3 .. test equipment/meters/measuring equipment
6 .. films, slides, transparencies, graphics
7 .. equipment trainer/mockup
4 .. not taught/NA
1 .. components from damaged equipment
2 .. TOs
1 .. programmed text

b. What various equipment parts look like before and after a maintenance action

20 .. actual equipment
2 .. equipment parts/disassemble component
4 .. slides, transparencies, graphics
2 .. TOs
10 .. not taught/NA/no specific training
4 .. equipment trainer

Q-8 Maintenance personnel can learn the visual cues which distinguish between normal and abnormal conditions. Also, these cues can be *shown graphically in Technical Orders. Can you see any reason why* maintenance men should memorize the difference between good and bad equipment conditions when they can readily find this information in a well-constructed Technical Order?

6 .. should memorize major indications
2 .. TOs contain errors
6 .. hard to use TO information, have never seen a well constructed TO
13 .. TOs don't show both good and bad indications. Need for monitoring.
10 .. TOs can't cover everything; don't contain all visual cues
18 .. must follow TOs in some AFSCs; seldom used in some AFSCs
7 .. TOs don't isolate fault to a specific part

Part I, Section 4

Q-2 With respect to the part-task trainers available for your use:

a. What do you like most about them?

2 .. ease of accessibility
1 .. location of trainers
16 .. they are AETs and students can work on real equipment/realism/ can operate real equipment
1 .. relive actual equipment from possible damage
1 .. good for testing students
1 .. simulates actual equipment
1 .. can insert faults
1 .. use actual components
1 .. training capacity
7 .. not applicable
1 .. only thing we have

b. What do you dislike most about them?

1 .. AET is dummy loaded
2 .. very noisy
3 .. AETs too old/worn out/parts missing
1 .. can't get inside equipment
5 .. too much maintenance downtime/lack spare parts
6 .. doesn't resemble actual equipment/unrealistic configuration
3 .. nothing
8 .. not applicable
1 .. doesn't use actual components
1 .. not operational
1 .. can't practice some tasks

Part II, Section 5-A

Q-6 With respect to the System Specific Troubleshooting Trainers available for your use:

a. What do you like most about them?

3 .. use AETs
1 .. can show overall system operation
2 .. can insert and remove faults
4 .. provides "hands on" training
1 .. easy to use
1 .. specific system isolated from associated equipment
2 .. easy access to checkpoints as compared to AET/visibility
1 .. builds use student's confidence in troubleshooting capability
1 .. good representation of end item
2 .. easy to demonstrate logic flow/good for demonstrations
1 .. can direct students to specific equipment parts and problems
1 .. saves wear and tear on equipment
1 .. can use in more than one course

b. What do you dislike most about them?

3 .. can't insert fault within stage/module/drawer; can't teach troubleshooting
1 .. not enought fault insertion capability
2 .. malfunctions that are inserted are unrealistic at times/readings unrealistic
1 .. time consuming to use AET
3 .. doesn't show interrelation between system components; can't relate to complete system
1 .. takes up too much space
1 .. don't completely support course requirements
1 .. unrealistic
1 .. normal environment affects readings

Q-7 Would you make more use of Systems Specific Troubleshooting Logic Trainers if they were made available to you?

a. Comments accompanied by "yes" answer

1 .. AET downtime means that much training inadequate or nonexistent
1 .. can use to show operations
1 .. would use if they were configured
1 .. would use simulator if more versatile and provided better training environment
1 .. OK if trainer can present "real world" situations
1 .. $ are preventing development of trainers which can be "bugged" for troubleshooting training
1 .. would like a trainer for teaching the logic values of ICs
1 .. could use more simulators of a similar type
1 .. general purpose trainers more practical for 3-level training
1 .. would use if they were needed

Q-7 (Cont'd)

b. Comments accompanied by "no" answer

1 .. can't use to troubleshoot or show interconnections between units
1 .. can only use AET or very hi-fi simulator
2 .. not practical for this course (meterology)

Part II, Section 5-B

Q-4 With respect to the general purpose trainers available for your use:

a. What do you like most about them?

2 .. can show overall system operation, how system works together
1 .. saves wear and tear on equipment
4 .. good for student motivation; good for apprentice training
1 .. don't expose students to high voltage
1 .. need less time to teach theory
1 .. small, inexpensive
1 .. allows for good instructor/student ratio
2 .. simplicity; easy to insert faults
1 .. versatile
3 .. can apply training received to a wide variety of equipment
1 .. realistic

b. What do you dislike most about them?

1 .. not enought trainers per class
1 .. trainers too complicated
1 .. technical data too brief for trainer
2 .. hard to get repair parts/high down time
1 .. trainers obsolete
1 .. can't use in field environment
1 .. limited application

Part II, Section 5-B

General Comments by Respondents

.. Since 3-level repairmen don't troubleshoot why bother to teach this skill?

.. Instructors would like to teach troubleshooting and change 3-level course standards.

.. Students spend a lot of time on troubleshooting because they don't understand theory and how to apply it.

.. Most troubleshooting training should occur during OJT where it occurs in the job environment

.. Would like to teach more troubleshooting but limited by ATC.

.. Regard measuring equipment courses, spend lot of time on calibration but little time on troubleshooting.

.. Student has to know how equipment works before he can troubleshoot it.

Part II, Section 6

Q-2 With reference to the use of job segment trainers and simulators:

a. What do you like most about such trainers and simulators?

2 .. training equipment accessible to more students/low instructor/student ratio
1 .. low noise level
1 .. versatility
2 .. good for teaching front panel controls and operational procedures
6 .. low cost; cheapt to operate; low maintenance
3 .. allow for more realistic troubleshooting/fault insertion capability
1 .. trainer specifically designed for training
1 .. can study specific systems (engines)
5 .. shows actual operation/process on a miniturized scale/can show more realistic, complete system
1 .. provides some hands-on experience
1 .. easy to use
1 .. eliminates need for two different aircraft

Q-2 (Cont'd)

b. What do you dislike the most about such trainers and simulators?

1 .. poorly designed peripheral equipment
1 .. lack of "hands on" experience
1 .. don't support enough of course
2 .. troubleshooting capability not adequate for 5-level course
1 .. takes long time to get trainer configured when equipment modifications occur
1 .. some trainers too complicated for 3-level students
2 .. doesn't adequately simulate job conditions
1 .. can't troubleshoot inside LRUs
1 .. lack of information about trainers (poor TO for trainer?)

c. Are there other training devices you would like to use in place of job segment trainers and/or simulators?

1 .. we use slides and pictures to show actual shelters (portable radar shelter)
1 .. AETs with malfunction insertion authorization
1 .. Basic logic troubleshooting modules for electronics
1 .. need more field trips (civil engineering)
1 .. have to use actual equipment/can't use simulation in this course
1 .. need an AET or operational equipment
1 .. table-top simulator or our flight simulator

Part II, Section 7

Q-2 With reference to the use of Actual Equipment Trainers:

a. What do you like most about such trainers?

24 .. realism/show actual configuration/get feel of real equipment
7 .. good for component location and identification/high fidelity
1 .. need AETs to teach calibration
2 .. don't have to explain difference between simulator/trainer and equipment
1 .. can use system TOs
1 .. use because no mock-ups or simulators available
1 .. can fault isolate to a part rather than to a component area
2 .. provides "hands on" experience
2 .. helps overcome student's fear of equipment
2 .. faults easy to insert (faulty cards)/easy to use to teach students
1 .. students can learn to use BITE
1 .. equipment is durable
1 .. helps motivate students
1 .. can simulate important operating conditions
1 .. inexpensive

Q-2 (Cont'd)

b. What do you dislike the most about such trainers?

1 .. have to dedicate classroom for particular blocks of instruction
3 .. high operating costs
1 .. maintenance personnel from CMS cannot repair
1 .. permanently installed
1 .. high level of maintenance and housekeeping tasks
2 .. high initial costs
11 .. can't take wear and tear/unreliable/can't get parts
1 .. travel and preparation time is high
3 .. only small number of students can be trained at one time
7 .. lack of fault insertion/simulation capability; limited versatility
1 .. tend to lose trainers to the field (if configured)
1 .. obsolete
1 .. too complicated for teaching theory and troubleshooting
1 .. limited application (doesn't cover much of course)
1 .. poor TOs
2 .. hard to provide feedback to students/not designed for training
1 .. high noise level

c. Are there other training devices you would like to use in place of AETs?

1 .. extensive AV aids
1 .. trainers to teach troubleshooting
3 .. high-fi simulators
1 .. need something but not sure what
1 .. need an AET
1 .. need some part-task trainers
1 .. need some simple, general purpose trainers designed for training
1 .. a simulator would allow for more troubleshooting practice and student feedback
1 .. use simulators to reduce wear and tear/maintenance/operating costs, provided that they were used along with AETs

Appendix E

QUESTIONNAIRE A

Comments Provided to Multiple-Option Questions

Many multiple-option questions contained an "other" response option. When this was chosen the respondents provided comments to explain or justify their selection of that option. In addition, many instructors provided explanatory comments to many multiple-option questions. All comments which seemed of interest are contained in this appendix. The alpha-numeric code in ( ) after many comments identifies the respondent.

Part I, Section 1

Q-1 A basic student fresh from the civilian world often enters the automatic flight controls course thinking that an autopilot is something that is about to be invented. Demonstration of an actual autopilot system in operation is usually a great motivation for those students. Fidelity is very important in this sense.(C9)
Mixture of real equipment and training aids has to be the best.(C6)

Q-2 All demonstrations are on live equipment in laboratory setting. (C1)

Q-3 No: Could not show internal parts clearly.(S11)
Some non-operating mock-ups are segmentized to be able to show "Black Box" removal/replacement procedures. (L8)
Two dimensional. Doesn't prove a "feel" for the devices. (K15)
You cannot understand the unit operation. (C2)
Our students are involved in a self-paced set up and charts and transparencies will not be feasible in this training environment. (C8)
I do not feel charts and transparencies can effectively meet all training objectives. Examples: using various motors or valves disassembled you can show complete view of parts relationship. (C10)
Only to an extent. Transparencies and charts are limited in operation and are not as flexible as active components for teaching R&R, Repair of subassemblies, laws of physics at work inside components. (C9)

Q-4 Cannot substitute for real equipment due to continual change on aircraft systems. (L3)
In regards to a portion of the equipment, e.g., a subassembly or part which has become defective, it would be more advantageous for the student to see the actual insides of that piece or part. (K9)
For theory, yes. For hands-on tasks such as alignments and trouble-shooting, no. (C1)
No: Internal working mechanism difficult to show in proper perspective.(C4)
No: Each student progresses at his own rate of speed and must use the equipment at different times. Wall charts and transparencies would not work. (C8)

Q-5 Other: Use slides and transparencies in lieu of mockups and cutaways because we have found them to be less expensive, yet effective. (S4)

Other: Great deal of course deals with hands-on requirements. Actual key system equipment is used, and is effective (Telephone equipment installer) (C12)

No: Now have real equipment. It would be less productive and more expensive to procure simulators for that protion of course where AETs are used. (L1)

Other: AETs are also necessary for practical work in alignment and troubleshooting. (L4)

No: This is a 5-level course in nuclear weapons. Students must be qualified before operating equipment.. Devices other than AETs would cause slower learning. (L21)

Other: In our course (nuclear weapons) only operational training equipment constructed by AEC/AEDA contractors could be used to effectively train students. Our course is primarily a "hands-on" course. (L25)

No: Realistic does not necessarily mean expensive. Maintenance of equipment is, in itself, expensive; but poor teaching methods will result in a poor maintainer, raising basic maintenance costs. (K15)

No: I feel that in training computer specialist actual hands-on training on real equipment is more effective. (K19)

Yes: For theory, yes. For hands-on tasks, such as alignment and troubleshooting, no. (C1)

Yes: We are already using charts, movies, etc. where most effective.(C4)

Yes: This applies only to knowledges. (C7)

Yes: Any training device is welcome if it can meet the training objectives. (C10)

No: I don't feel that wall charts, etc. can meet the training objectives. Cost should not be the sole factor for determining which training device/aid to use. (C10)

__Part I, Section 2__

Q-1 Other: Equipment parts are taught in the "sets" portion of the computer course. (K19)

a. Self-paced course. Students read about equipment in PT or pamphlets before actually working with equipment. (C6)

Q-2 Other: We use a combination of whole and disassembled equipment to supplement PTs and illustrations. Whole equipment used primarily for subsequent stages of learning, but has been utilized quite often and with great effectiveness during early stages.

Q-4	Other:	TOs provide location diagrams for all equipment. (L2)
	Other:	Pictures, diagrams incorporated into programmed texts. (C6)
	Other:	Use video tapes to explain parts of equipment then students use AETs.(C8)
	Other:	Don't concentrate on equipment location. We use our trainers as "A typical autopilot system," not as a specific system. Each aircraft the student works on will have a different location for components, and each autopilot system has different components. (C9)
Q-5	Yes:	Most packaged material would only be a repeat of TO material.(S1)
	No:	Systems change rapidly and test and handling equipment or procedures would be hard to follow if pre-packaged. (L25)
	No:	We are using video tapes which we have developed and this works quite well. (C8)
	No:	Feel that each course should develop their own training aids. When this done, Instructor ideas considered for approval prior to building aids. (C10)
Q-6	Yes:	Pictures and drawings are only effective up to a point, than AETs needed. (L4)
	Sometimes:	Often, graphics do not illustrate real parts or tools to their fullest. (L7)
	Yes:	In the case of special tools and equipment, in many instances it is necessary to develop a "feel" for the tool or device in order to understand complete its total function and efficiency. (L8)
	No:	Not if the learning is to a knowledge level only. (L24)
	Yes:	It is very hard to visualize location, size and proper precautions when using graphics. (L25)
	No:	I feel that it is more effective for the student to see the actual part than to see a graphic. That does not mean he has to touch or feel it. (K19)
	No:	Provided that more realistic training is provided later.
Q-7	Sometimes:	It should be done in combination with a nomenclature package and job context. (L1)
	Yes:	The language of the job is what should be taught. Tech School definitions for real job nomenclature don't mix. (L6)
	Yes:	Students learn easier and faster with actual equipment. (L7)
	Sometimes:	Both. Many items that are used have shortened or "pet" titles when used in the field, and it could be hard to associate the (proper) nomenclature taught once the student is in the field. (L25)
	Yes:	Nomenclautre has more meaning if the student learns it while they are learning about that piece of equipment. (L9)
	Yes:	The level of most of the students in the jet engine course cannot learn from programmed packages by itself. (C7)
Q-8	Sometimes:	Prepackaged material may help but finalization of training would require actual equipment. (L4)

Q-9 No: Some students can't read.

No: Just because the information is contained in a TO does not mean it can't be taught or that it shouldn't be. (L2)

No: On many items or test sets, troubleshooting indicators may not be a part of normal displays, and specific locations must be known as troubleshooting tests must be accomplished during an automatic, timed sequence.
Excessive delay in finding the indicator could result in invalid information.
This is true also for some weapons checkout procedures. (L8)

No: Students do not need to memeorize the location of controls or parts because it changes from one piece of equipment to the next. Example is an O-scope.
It is more important for a student to learn how a scope works so its operation can be applied to any mode of the O-scope rather than learn where the controls are located on a given model. (L9)

No: Location of equipment displays, controls, parts, etc. are essential to troubleshooting. They must be taught in order to produce a good technician. (K19)

Yes: These items vary from aircraft to aircraft and we instruct all AFCS system specialists. (C9)

<u>Part I, Section 3</u>

Q-3 Yes: Many sounds and odors in this career field would be helpful since we work on engine, hydraulic and electrical equipment. (C5)

No: Rather use AET so can relate sound to the cause. (L6)

Q-4 Probably would. Has been done. However, in many cases the material used for odor identification could be hazardous to health, particularly in identifying leaking propellants. (L8)

Q-7a No: Would be difficult to familiarize student with what effect maintenance actions would have without using AETs.(C1)

No: In electronics there is seldom a visual cue present. Aside from troubleshooting indication, that can be used to discriminate a good part from a bad part. (C9)

Q-7b Yes: We have very few faulty parts to use in this respect. We do have a few slides showing accident results and their cause. (L25)

No: Why use pictures when actual equipment is available? (S10)

Yes: What defective electronic components look like is something we could show via slides, actual components, etc. (C1)

No: In this course a good part can have the same appearance as a bad part. (K23)

No: 90% of our parts are depot-level repair, not field-level repair.(L7)

Q-8 Yes: Good information about visual cues not contained in TOs (L4)
Yes: People should have a "top of the mind" awareness of a concept and not rely on a book. (L6)
Yes: I have never seen a truly well constructed TO. (K5)
Yes: If the person does not recognize an abnormal condition he will not refer to the TO. (5)
Yes: Should memorize major indications but not all indications. (K9)
No: Most technicains will do a maintenance job according to the TO when at all possible. It is a coverall. (K22)
Yes: A normal indication can go abnormal more than one way. The combination of bad indications cannot be fully simulated or covered in a TO. YOu have to see it to believe it. (C1)
Yes: Not all types of visual cues are given in the TO. (C2)

<u>Part 1, Section 4</u>

Q-3 Probably would. In troubleshooting some of our modularized equipment, defective modules, cards, chassis assemblies could be troubleshot on a bench with just the sub-unit connected. (C1)

Q-4 Use in less than 10% of course. Part task trainers we have are not cost effective. (L24)

<u>Part II, Section 5-A</u>

Q-2 Other: A combination of TOs for technicians of troubleshooting and AETS for fault isolation/clearance. (S18)
b. System logic trainers are great but to individuals who have not seen the weapon system, whole-part-whole would be advantageous.(S24)
a. Because I can't visualize a method of simulating equipment that we have to maintain entirely (internal adjustments and repair).(L16)
Other: Simulator (Hi Fi duplicate of actual equipment).
Other: Simulator designed specifically for training purposes. Possible also, a trainer for specific logic and solid-state malfunction troubleshooting. A trainer to include basic counters, flip-flops, registers, etc. (L19) (Will make use of 6883)

Q-3 Yes: TOs are not written in a manner to aid a 3-level. You must know the system to understand the TO in many cases.
Yes: Some TOs used contain troubleshooting flow charts, or specific areas dealing with troubleshooting. (K11)
Yes: Maintenance training concept for this system is entirely TO oriented. (C15)

Q-4 No: TO cannot cover everything that can happen to a system. TOs are good, but they have a way of leading an individual into a false sense of security. Most people that use TOs regularly forget how to think on their own. (S22)

No: TOs cover theory of operation, not correction factors and repair, unless technician has a deep theoretical physical background (physical measurement and calibration course). (L20A)

No: AGE equipment technical orders need more technical material pertaining to theory of operation and definite maintenance procedures.

Sometimes: The complexity of the typical flight simulator makes detailed troubleshooting procedures (description of?) unfeasible. (C27)

Other: TOs are written at too high a grade level for our students. (C30)

Q-5 Yes: Logic trainers would be good, but hands-on training on actual equipment is also needed in order to facilitate learning. (S24)

No: Using a high-fidelity duplicate would be OK. (L17)

No: Could use Hi-Fi simulator with inherent training advantages--programmable faults. (L19)

No: For 5-level course should use AETs when possible. (K14)

Yes: Students should be required to apply their knowledge and skills on the actual equipment. (C18)

Yes: We can only train people in preparation for work on approximately 7 different flight simulators. (C28)

Q-7 No: Not presently used and cannot see the feasibility in this course.(S14)

No: See no way a simulator could substitute for the real thing, especially when checking individual drawers. (S17) (See CDF note under Sec. 7.)

Probably would: I am not sure if a trainer could be made to troubleshoot telephone cables. (S20)

Probably would: The reason would be if only a better understanding of a system or systems could be guaranteed from use by the students, and only if the possiblity of TCTO changes could be incorporated. We now have Class I trainers which are undated with the system.(S24)

Probably would: At present, down time of real equipment is such that a lot of training is either inadequate or nonexistent. (L15)

Not certain: Would be good to show front panel controls and operation, but couldn't be used to go inside the units and troubleshoot circuit cards and interconnections between the units of the test station. (L16)

No: Our course is 13 years old. The equipment is being removed from the USAF inventory. It is no economical to make trainers at this stage. (K10)

Yes: However, they would have tc provide a superior training environment compared to the actual equipment in terms of versatility. (K12)

Yes: Lack of money is preventing engineering studies which would lead to a supply of "bugged" equipment for training use.

Yes: We like what we have, but could use more of them for other systems in the course. (Course uses part-task trainers). (C24)

Probably would: Systems specific equipment would be OK, but general type trainers are more practical for apprentice level training.

Part II, Section 5-B

Q-1 Collins 7404a Source Generator is designed to checkout/monitor a variety of Collins-developed equipment (digital computers).

Q-2 AD/DC circuit troubleshooting trainer allows students to determine faulty components and to determine corrective action. (S16)

Yes: Pump trainers and pipe trainers used to simulate malfunctions (Environmental support specialty course). (S21)

Yes: Use electrical troubleshooting trainers that are adaptable to any electrical training course. (S22)

Q-3 Would prefer to use systems specific trainers for equipment portion of course and general purpose trainers for fundamentals of electronics. (S18)

Prefer to use system specific trainers assuming that frequent equipment modifications can be incorporated into trainer. (L15)

Other: Prefer to use real equipment of a Hi-Fi simulator. (L17)

We use both types. One (SB3390) checks the system while in operation. The 7404A is for specific equipment checkout. (K14)

Q-5 In our course (missile control communication system specialty) neither specific or general purpose troubleshooting logic trainers could be used effectively. (S17)

Over the years a constant or chronic complaint from military instructors has been that 3-level people don't do the troubleshooting. Therefore it is senseless to attempt (to teach) troubleshooting techniques (in a 3-level course). I'm unsure of the validity of this feeling but it plays a part in selecting training objectives as well as trainers. I'm wondering if increased use of troubleshooting trainers were attempted what the outcome would be. (L19)

Would like to teach troubleshooting as much as possible but ATC limits on course lengths limits the time (provided for troubleshooting).

Part II, Section 6

Q-1 Titan II power plant simulator simulates power plant found in the Titan II missile silos. Trainers used in advanced course. (S16)

Will soon receive 6883 test-bench simulator. (L17)

The AN/TSC-60 is a transportable shelter (communication equipment). We have the interior equipment expanded in the classroom (for ease of access). (K14)

Yes: In aircraft areas of 3160T an aircraft trainer is used with instructor panel that is used to simulate faults and operation. All other areas use actual equipment for training. (C20)

Part II, Section 7

Q-1 Yes: What we have falls short of what we need. If we had or could get an AET it would be used extensively. (C22)

Q-4 "b" We are not convinced it would be feasible for our course--missile control communications system specialty. (CDF Note. EB and EC trainers have many similar cabinets and drawers. BITE used to isolate fault to a drawer or cable between cabinet. Test bench used to check out drawer. Many redundant portions of system could be simulated and a great reduction in cost and space. Same also applies to autovon equipment). (S17)

"c" I don't really know how you could go about applying the use of low cost simulators to a job in water (treatment plants) that is accomplished by mechanical and chemical means. (CDF trainers consist of miniature water or sewage treatment plants. (S21)

"d" One problem area would be the modifications that take place on our equipment. Would we be able to keep up (with new configurations)? (L15)

"d" I am an advocate of hi-fi simulators to be used in the 326xlc, etc. career field training at Lowry. These simulators (6883, e.g.,) will be less costly, more reliable, and more realistic (due to unlimited malfunctions that can be inserted) than AETs. Honeywell is producing a prototype for us now that should prove these points. We also have submitted requirements for four more simulators for the F-111, and simulators for the F-15 equipment. (L17)

"d" Essentially same comment as (L17).

"a" Trainers are not practical for this course (Precision Dimensional and Optical Measuring Technician). The majority of this course teaches certification (calibration of equipment) and alignment.

QUESTIONNAIRE A, PART II

General Comments Offered by Respondents

K-10[1] Course 13 years old. Equipment being removed from AF inventory. Nor economical to replace with trainers.

K-11 Portions of course would be useless without AET. Need AET to teach operation of a complete system (scope control).

K-12 Training equipment about to be replaced. Simulators of no value therefore.

K-13 Equipment will be phased out in a few years therefore simulators of no value now

K-14 Currently we use a mix of AETs, specific & general simulators, and job segment trainers. Combination is excellent.

L-11 Would have liked a briefing on specific examples of simulators.

L-12 Students have difficulty relating training to equipment unless use an AET.

.. Difficult to teach troubleshooting when using an AET

.. Computer-based troubleshooting simulators could be adapted to some of course

L-13 Should stress basic training, using basic troubleshooting trainers for electronic circuits.

.. *Use of AETs greatly* limits training versatility

L-14 Difficult to use simulators for maintenance of precision measuring equipment.

L-15 Have to work out procedures for undating trainers.

L-16 Can't use simulators to teach maintenance of precision measuring equipment.

.. As an Instructor, I don't like conflict between trying to do a good teaching job and ATCs desire to cut training cost.

L-17 I am an advocate of simulators (involved with 6883)

L-19 I am an advocate of simulators (involved with 6883)

.. I question the use of OJT trainers

L-20a Need AETs for teaching calibration/repair of precision measuring instruments.

L-20b Dimensional and Optical repair can't be duplicated using trainers.

C-12	Have to teach on real equipment for a 5-level course.
C-16	I am willing to use simulators if training satisfies user requirements.
C-17	Current simulators cost more than actual equipment.
C-22	Would like simulators that can be reprogrammed for different types of equipment.
C-27	Media mix (and simulation) concept lends itself well to our field (digital flight simulation).
C-28	Media mix (and simulation) concept lends itself well to our field (digital flight simulation).
C-29	Sometimes must use an AET because simulators can't do the job.
S-14	Would be too costly to simulate the telephone (AUTOVON?) exchange equipment.
	.. Student has to become accustomed to equipment noise and sounds
S-15	Basic helicopter course has no requirement for troubleshooting.
S-16	Substituting simulators for installed equipment in an on-going course does not seem cost-effective. Can see possibilities for future courses.
S-17	Don't see role of simulators in missile communication courses.
S-20	Easy to use actual cable trainers and troubleshooting test sets (in a cable splicing course). They are rugged, easy to carry and to use.
S-21	Simulators not applicable to water treatment process.
S-23	AETs have been used for a long time and have proven their effectiveness for training.
S-24	Need for helicopter trainers depends on course level.

[1] These are ID numbers of respondents. K=Keesler AFB; L=Lowry AFB; C-Chanute AFB; and S=Sheppard AFB

QUESTIONNAIRE B, PART I

General Comments Offered by Respondents

Sheppard AFB

S-2	Training equipment not up to date. Training and operational equipment does not have malfunction insertion capability.
S-12	Training equipment obsolete (telephone switchboards).
S-17	Breakdowns seldom occur, but difficult to repair when they do occur. Instructors have reviewed possibility of developing training equipment with more faulty insertion capability but discarded notion because of costs.
S-18	Training equipment is adequate provided training load does not increase. Too costly to provide air conditioners to handle those occurrences when building A/C can't handle load (Electronic switching systems).
S-19	Troubleshooting not effectively taught because not considered part of 3-level training.
S-21	Some CE (civil engineer) simulators (e.g., water processing) should be able to produce actual product.
S-22	No capability to train students on lithium bromide absorption system (A/C course).

Lowry AFB

L-11	Need mockup of aircraft to support original maintenance.
L-12	Teaching troubleshooting is difficult due to high noise. Also, very time consuming.
L-13	AETs lack capability/versatility to teach troubleshooting.
L-15	Test stations and LRUs malfunction rather frequently. When this occurs students taught only theory as opposed to hands on practice they are suppose to receive.
L-16	Have problems maintaining equipment (Test stations). Can't modify equipment for training (because it is class I trainer).
L-17	High rate of training equipment breakdown (Test stations). Test stations can be recalled by TAC.
L-19	Can't insert malfunctions in AGE trainers. Can't modify training equipment. Can't do certain things that might damage trainers. High rate of down time awaiting maintenance and parts.
L-24	AETs cheaper and more effective (Avionic Sensor Systems).

Keesler AFB

K-3	Course being revised. Some AETs being eliminated, others being added.
K-5	Use AETs and not allowed to modify them. Course being revised. Eventually will use TPS-43E BITE simulator (see note #1).
K-6	AETs will be replaced in early 80's.
K-8	New AETs will be introduced into course.
K-10	Equipment is to be replaced by minicomputer.
K-12	Equipment is inadequate due to nonavailability of parts.
K-16	"Realism" does not necessarily mean "expensive", especially if it results in better learning which then leads to better equipment maintenance.
K-19	Need AET to train computer maintenance specialist.
K-15	Training equipment repair is a problem because it takes long time to get parts.
K-16	Using a substitute radar for training because actual equipment is too expensive.
K-18	Need more equipment to handle student load (already have 18 AETs - CDF).
K-19	Equipment limited because used by more than one course. When using AETs for training, all equipment modifications have to be authorized.
K-23	Equipment is not available for some course blocks because of high cost of equipment.

Chanute AFB

C-15	Have scheduling problems when equipment needed in tow or more classes.
C-16	AETs are subject to recall to the field, and you can't insert faults into them.
C-22	Don't have equipment needed to support training (Digital navigation/ tactical training device specialty). T-10 has never been configured in all systems needed for training.
C-23	Missile trainers not appropriate for a 7-level course.
C-24	Can't get parts for trainer.
C-26	Need more fault insertion capability.
C-27	Trainers old and break down; they can't be modified; they are too expensive.
C-28	Same comments as C-27.
C-30	Limited fault insertion capability. Downtime causes delays in training. Trainers too expensive.

Notes

1 (K-5) This course is being revised. Present course supports AD radars. In future FAA will take over this training and Keesler will train and provide support for radars that operate in a tactical mobile environment. The TPS-43E radar is scheduled to become the radar for AC&W. Keesler will implement 3-level training on new radar course in April 1979. In the meanwhile, the present training equipment will be used to teach a few students goind to ADC.

There is a feasibility study currently under way to develop a simulator for training on the TPS-43E, and it is expected that the simulator will be produced and used in place of the actual radar.

CDF -- simulator will represent the BITE for the TPS-43E. It may also allow for occurrence of some type of radar operator training but that hasn't been decided yet.

Procedures for Determining Simulation Potential for Resident Training Equipment

Steps

1. Determine unit cost of RTE (Resident Training Equipment). Enter Table XII-A and determine cost rank. Example: A unit cost of 267K ($267,000.00) equals a rank of 15. (For any two adjacent ranges in Table XII-A the upper limit of the second range is approximately 20% above that for the first range.)

2. Determine number of hours of unscheduled maintenance performed on RTE during a recent 12-month period. Enter Table XII-A and determine the maintenance rank. Example: 63 hours of unscheduled maintenance equals a rank of 7.

3. Determine sum of responses to the six parts of Question 1, Part II, Questionnaire B. Each of the six parts of Q-1 addresses an issue relating to the effectiveness of a RTE for supporting maintenance training. For a highly effective trainer all six parts might be answered by a "1". For a highly ineffective trainer all parts might be answered by a "3" or a "4".

4. Determine response to Question 2, Part II, Questionnaire B. It represents the number of RTEs available for training. The more RTEs in current use the greater the potential for replacing one or more of them with a simulator.

5. Determine response to Question 3, Part II, Questionnaire B. A response of "1" or "2" represents a desire for more AETs. A response of "3" or "4" reflects a judgement that additional AETs are either not needed or not wanted. Convert all 1 and 2 responses to a response of "2". Convert all 3 and 4 responses to "1". If an instructor wants additional AETs this provides a possible opportunity for convincing him that simulators could be used instead of AETs.

6. Determine the response to parts a, b and c of Question 4, Part II, Questionnaire B. The answers to Q-4 reflect the degree to which the respondent is willing to accept simulators in addition to or as replacements for AETs. A strong rejection of simulators is represented by the response pattern "4-4-4". A strong acceptance of simulators is represented by response patterns of "1-1-1" or "4-4-1". Enter Table XII-B and determine the "simulation acceptance" rank for the response pattern to Q-4. Example: A response pattern of "2-4-4" has a simulation acceptance rank of 7.

<u>Steps</u>

7. For any RTE, sum the ranks or numbers developed in accordance with the preceding six steps. Illustration: For the second listed RTE on Table VIII the ranks and numbers are 9,7,12,2,1,11 for a total of 42.

8. Enter Table XII-C and determine the "Simulation Potential" rank for the RTE under analysis. Illustration: The sum "42" calculated in step 7 represents a simulation potential rank of 7 which also has been defined as the 5th simulation priority level. A simulation rank of 11 represents the 1st or highest simulation priority level. Table IX of this report contains RTEs which had a simulation potential rank of 1, 2, 3 or 4.

Table XII-A. Definition of Ranks for RTE Unit Cost and Sum of Unscheduled Maintenance Hours/Year

Rank	Range
1	0 - 25 K dollars or man hrs. unsked maint.[1]
2	26 - 30
3	31 - 36
4	37 - 43
5	44 - 52
6	53 - 62
7	63 - 74
8	75 - 89
9	90 - 107
10	108 - 128
11	129 - 154
12	155 - 185
13	186 - 222
14	223 - 266
15	267 - 319
16	320 - 383
17	384 - 460
18	461 - 552
19	553 - 662
20	663 - 794
21	795 - 953
22	954 - 1144
23	1145 - 1373
24	1374 - 1648
25	1649 - 1978
26	1979 - 2374
27	2375 - 2849
28	2850 - 3419
29	3420 - 4103
30	4104 - 4924
31	4925 - 5909
32	5910 - 7091
33	7092 - 8509
34	8510 - 10211
35	10212 - 12053

[1]The same scale and rank definitions are used for both "initial cost" and "amount of unscheduled maintenance" because the same range of numbers is required to cover the values obtained for both factors.

Table XII-B. Definition of Ranks for Question 4, Part III, Questionnaire B

"Simulation Acceptance" Rank	Response Pattern to Q-4
1	4 - 4 - 4
2	3 - 4 - 4
3	4 - 3 - 4
4	4 - 4 - 3
5	3 - 3 - 4
6	3 - 3 - 3
7	2 - 4 - 4
8	2 - 3 - 4
9	4 - 2 - 4
10	2 - 2 - 4
11	2 - 2 - 3
12	4 - 1 - 4
13	1 - 4 - 4
14	2 - 1 - 3
15	1 - 2 - 3
16	3 - 3 - 2
17	2 - 1 - 2
18	1 - 1 - 4
19	1 - 1 - 3
20	2 - 2 - 2
21	1 - 1 - 2
22	4 - 4 - 2
23	4 - 4 - 1

Note: A blank response equals "4".

Table XII-C. Definition of "Simulation Potential" Ranks and "Simulation Priority" Levels

"Simulation Potential" Rank	Range of Sum of Ranks and Numbers	Simulation Priority Level
1	0 - 15	11th Priority
2	16 - 18	10th Priority
3	19 - 23	9th Priority
4	24 - 28	8th Priority
5	29 - 34	7th Priority
6	35 - 41	6th Priority
5	42 - 49	5th Priority
4	50 - 59	4th Priority
3	60 - 71	3rd Priority
2	72 - 85	2nd Priority
11	86 - 102	1st Priority

Survey of Training Simulators (F33615-77-C-0051) — Appendix I

Courses Surveyed at Lowry AFB

G3ABR31631L	000	Missle Systems Maintenance Specialist (QZZ)
G3ABR31633	001	Instrumentation Mechanic (ELZ)
G3ABR32130K	000	Bomb Navigation System Mechanic (AFA)
G3ABR32131E	000	Defensive Fire Control System Mechanic (B-52H: ASG-21 Turrets (AHQ)
G3ABR32131G	000	Defensive Fire Control System Mechanic (B-52D/G: MD-9, ASG - 15 Turrets (AHN)
~~G3AZR32150G~~	~~000~~	Unit Test Equipment (AN/ASQ-38) (C5B)
~~G3AZR32150K~~	~~001~~	Electro-Optical Viewing Systems AGE Technician (B-52G/H (S3Q)
~~G3AZR32171K~~	~~000~~	Defensive Fire Control Systems Technician (SRC)
G3ABR32132A	000	Weapon Control Systems Mechanic (F-106A/B;MA-1, ASQ-25 Systems (AWX)
G3ABR32132N	000	Weapon Control Systems Mechanic (F-105D/F;ASG-15 Systems) (AWO)
G3ALR32152C	000	Weapon Control Systems Mechanic (F-106A/B;MA-1, ASQ-25 Subsystems) Intermediate (RMM)
G3ABR32430	002	Precision Measuring Equipment Specialist (PVS)
G3ABR32430	003	Precision Measuring Equipment Specialist (Army 35H20)(S9S)
G3ABR32630C	000	Avionics Aerospace Ground Equipment Specialist (MG-6)
G3ALR32630A	000	Avionics Aerospace Ground Equipment Specialist (F-15 Manually Operated Avionics AGE) (UW6)
G3ALR32630B	000	Avionics Aerospace Ground Equipment Specialist (F-16 Automatic Avionics AGE) (UW5)
G3ABR32631A	000	Integrated Avionics Component Specialist (FB-111, AGE, etc.)
~~G3ABR32631B~~	~~000~~	Integrated Avionics Component Specialist (Communications/Mission and Traffic Control and Penetration Aids) (MLA)
G3ALR32631D	000	Integrated Avionics Component Specialist (Automatic AGE) (UW8)
G3ABR32232B	000	Avionic Sensor Systems Specialist (Tactical/Real Time Display)
G3ABR32232C	000	Avionic Sensor Systems(Electro-Optical)
G3ABR32470	001	Precision Measuring and Calibration Technician
G3AAR32470	002	Precision Dimensional and Optical Measuring Technician
G3ABR32132N	000	Weapons Control Systems Mechanic (F-105, R-14A Radar)
G3ABR32232A	000	Avionic Sensor Systems (Recon)
G3ABR30435	000	Television Equipment Repairman
~~G3ABR46230~~	~~004~~	Weapons Mechanic (ADC) (AW4)
~~G3ABR46230~~	~~007~~	-TAC/ANG-RES (QVM)
G3ABR46330	000	Nuclear Weapons Specialist (AQH)
G3AZR46350	001	Nuclear Weapons Specialist (Minuteman III)(HS8)

[1] Lined out courses were not surveyed.

Appendix I

SURVEY OF TRAINING SIMULATORS

(F33615-77-C-0051)

Courses Surveyed at Sheppard AFB)

J3ABR31632F	006	Missile Electronic Equipment Specialist (ELX)
J3ABR36130	000	Outside Wire and Antenna Maintenanc e Repairman (AQV)
J3ABR36131	000	Missile Systems Cable Maintenance/Splicing Specialist (AFS)
J3ABR36132	000	Cable Maintenance/Splicing Specialist (AFW)
~~J3AZR36150~~	~~001~~	Outside Plant Installation and Maintenance (CMA)
~~J3AZR36154~~	~~001~~	Cable Maintenance/Splicing Specialist(General) (BJ4)
J3ABR36231	000	Telephone Switching Equipment Repairman, Electro/Mechanical (AVJ)
J3ABR36232	002	Electronic Switching Systems Repairman(490L Overseas AUOTVON) (M3N)
J3ABR36233	000	Missile Control Communications Systems Repairman (APY)
~~J3AZR36252~~	~~000~~	Electronic Switching Systems Repairman (490L Overseas AUTOVON) (HD9)
~~J3AZR36252~~	~~001~~	AN/TCC-30 Electronic Switch O/I Maintenance (JBC)
~~J3AZR36252~~	~~002~~	Traffic Data Collection System Maintenance (SN2)
J3ABR30632	000	Communications and Relay Center Equipment Repairman, Electro/Mechanical (AGK)
J3AZR30652	005	O/I Maintenance M-37 ASR Low Level Keying (N8T)
J3AZR42672	005	Jet Engine Technician (H-1F/H-3) (CAT)
J3ABR43130	000	Helicopter Mechanic (AL2)
~~J3ABR43131A~~	~~000~~	Aircraft Maintenance Specialist, Reciprocating Engine Aircraft (ABJ)
~~J3ABR43131C~~	~~001~~	Aircraft Maintenance Specialist, Jet Air One and Two Engines (AM3)
~~J3ABR42630~~	~~000~~	Aircraft Propeller Mechanic (PDH)
J3ABR42631	000	Reciprocating Engine Mechanic (AS8)
~~J3ABR43131F~~	~~000~~	Aircraft Maintenance Specialist, Turbo-Prop Aircraft (ABL)
J3AZR43170	002	Helicopter Mechanic, H-3 (B3B)
J3ABR31632F	000	Missile Systems Maintenance Specialist (LGM-25) (ELV)
~~J3ABR30631~~	~~000~~	Electronic-Mechanical Communications and Cryptographic Equipment Systems Repairman (KG3)
J3AZR43170	004	Helicopter Mechanic, H-1H (LOG)
J3AZR43170	006	Helicopter Technician, H-53 (N1S)
J3ABR54730	000	Heating System Specialist
J3ABR36234	000	Telephone Equipment Installer Specialist (EL2)
J3ABR30631	000	Digital Subscriber Terminal Equipment Repairman
J3ABR54330	000	Electrical Power Production Specialist
J3ABR56631	000	Environmental Support Specialist
J3ABR54530	000	Refrigeration and Air Conditioning Specialist

[1]Lined out courses were not surveyed.

Appendix I

Survey of Training Simulators

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Courses Surveyed at Chanute AFB

C3ABR30230	000	Weather Equipment Specialist (AXA)
C3AZR30270	004	AN/FPS-77 Meteorological Radar O/I Maintenance (Q31)
C3ABR31630G	002	Missile Systems Analyst Specialist, WS-133A-M Integrated (PX4)
C3ABR31630G	004	Missile Systems Analyst Specialist, WS-133B Integrated (ELP)
C3ABR31630T	000	Missile Systems Analyst Specialist (AGM-69A) (HZ9)
C3ABR31632G	001	Missile Electronic Equipment Specialist, WS-133A-M (M53)
C3ABR31632T	000	Missile Electronic Equipment Specialist (AGM-69A) (HOA)
C3AZR31670G	006	Missile Systems Analyst Technician (TEAT), WS-133A-M Integrated (PYT)
~~C3AZR31670G~~	~~010~~	Missile Systems Analyst Technician (TEAT) (WS-133B/CDB) (U8Q)
C3ABR32530	001	Automatic Flight Control Systems Specialist (Self-Paced) (NCW)
C3ABR32531	000	Avionics Instrument Systems Specialist (KCL)
C3ABR32632B	000	Integrated Avionics Systems Specialist (PQZ)
C3ABR34131	000	Instrument Trainer Specialist (ANE)
C3ABR34133	000	Analog Flight Simulator Specialist (T9B)
C3ABR34134	000	Digital Flight Simulator Specialist (T9C)
C3ABR34135	000	Analog Navigation/Tactics Training Devices Specialist (T9D)
~~C3AQR34137~~	~~000~~	Missile Procedures Trainer Maintenance (TN1)
C3ABR34136	000	Navigation/Bombing/Tactics Trainer Specialist (KZN)
C3ABR39130A	000	Maintenance Analyst Specialist (Aerospace Weapons System) (QQ7)
C3ABR42330	000	Aircraft Electrical Repairman (ACH)
C3ABR42331	000	Aircraft Environmental Systems Mechanic (ANZ)
C3ABR42333	000	Aircraft Fuel System Mechanic (ACA)
C3ABR42334	000	Aircraft Pneudraulic Systems Mechanic (ACP)
C3ABR43131E	000	Aircraft Maintenance Specialist (Jet over 2 engines) (ABG)
C3ABR44330G	002	Missile Mechanic, WS-133 (LTW)
C3ABR42632	000	Jet Engine Mechanic (AM5)
C3AAR42371	000	Aircraft Environmental Systems Technician (CEO)
C3AAR42373	000	Aircraft Fuel Systems Technician (A1B)
C3ABR42335	000	Aerospace Ground Equipment Mechanic (ABU)
C3AZR42355	000	EMU-12/E Generator Set (FDS)

[1] Lined out courses were not surveyed.

Appendix I

Survey of Training Simulators
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Courses Surveyed at Keesler AFB

E3ABR30331	000	Air Traffic Control Radar Repairman (ACD)
E3ABR30332	000	Aircraft Control and Warning Radar Repairman (AAK)
E3ABR30333	000	Automatic Trac king Radar Repairman (AD3)
E3AZR30372	004	AN/FPS-26A Radar Maintenance (D8L)
E3AZR30372	012	AN/FPS-66A and 67 O/I Maintenance (EOK)
~~E3AZR30372~~	~~015~~	AN/MPS-11, FPS-8, FPS-6, GPA-122 O/I Maintenance (JXP)
E3ABR30430	000	Radio Relay Equipment Repairman (AS2)
E3ABR30434	000	Ground Radio Communications Equipment Repairman (ALT)
E3AZR30451	001	AN/GRN-27 O/I Maintenance (K2E)
E3AZR30454	006	Ground Radio Comm unications Equipment Repairman(AN/FLR-9(V)(B1X)
E3AZR30454	011	Scope Control System O/I Maintenance (JHB)
E3AZR30454	015	AN/TSC-60 Communications Central O/I Maintenance (K34)
~~E3AZR30454~~	~~022~~	HF/SSB Tactical Ground-Air Radio System Transmitter Facility (EY8)
~~E3AZR30454~~	~~023~~	HF/SSB Tactical Ground-Air Radio System Receiver Facility (FY7)
~~E3AZR30454~~	~~026~~	484L System O/I Maintenance (FWS)
E3ABR30434	000	Electronic Computer Systems Repairman (QH2)
E3ABR30534	003	Electronic Computer Systems Repairman(RCC-EDLCC/SACCS) (AHO)
~~E3ABR30534~~	~~005~~	Electronic Computer Systems Repairman(AN/FYQ-47) (QR4)
~~E3ALR30554~~	~~001~~	Electronic Computer Systems Repairman(Weapons Control Computer Group, AN/FSQ-21/412L) (E87)
E3AZR30554	015	Common Digitizer, FYQ-47, O/I Maintenance (NK2)
~~E3ABR30534~~	~~006~~	Electronic Computer Systems Repairman(BUIC,AN/GSA-51A) (KRB)
E3ABR30534	007	Electronic Computer Systems Specialist(HM4118/407L) (UA1)
E3AZR30651	008	FGT-7 and 17, FGR-10 and TT-558 Maintenance (QXY)
E3AZR30651	015	TAM/CCU/FGT-7 and 17/FGR-10 and TT-558 Maintenance (SN9)
E3AQR30930A	000	Missile Warning and Space Surveillance Sensor-Radar Repairman, AN/FSS-7 (QXN)
E3ABR32831	000	Avionic Navigation Systems Specialist (AA8)
E3ABR32833	000	Electronic Warfare Systems Specialist (AJ2)
E3ALR32850A	001	Airborne Command Post CE Repairman (NCL)
E3ABR30431	000	Flight Facilities Equipment Repairman (AKC)
E3ABR30434	001	Ground Radio Communications Equipment Repairman (Titan II) (FDE)

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★U.S. GOVERNMENT PRINTING OFFICE:1979- 671-056/102